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Monterey, California

THESIS

A CALCULATOR ADAPTATION OF THE MARKOV CHAIN MODEL FOR MANPOWER ANALYSIS

by

Jeffrey Kendall Sapp

June 1983

Thesis Advisor: T. Swenson

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A Calculator Adaptation of the Markov Chain Model for Manpower Analysis

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the requirements for the degree of

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This thesis provides a foundation for the application of fundamental Markov analysis to manpower modeling in the Armed Services or in other similar organizations. A handheld calculator software package is introduced to assist students, military analysts, and others who model manpower systems. Markov analysis methods are incorporated in program software to permit discrete time investigation of the Navy's manpower structure. A user program guide for application to a broad range of manpower issues is also presented.

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The thesis is dedicated to the memory of my parents, Arthur Q. Sapp and Barbara M. Sapp, who were not able to see a dream realized in the education of their youngest son.

I. INTRODUCTION

> Technology is dominated by two types of people:
>
> Those who understand what they do not manage.
>
> Those who manage what they do not understand.
>
> --Putt's law

Human resources are the Military's most valuable asset and most difficult area to manage. The peacetime active duty military of the 1980s is composed of over two million men and women, representing several diverse organizations and a wide range of occupations. Each year the Armed Services, in conjunction, must recruit several hundred thousand new enlistees, and discharge and reenlist a few hundred thousand more in the effort to maintain an effective, capable force of proper size. The personnel management problems of the Military are compounded by the fact that it must operate in a dynamic environment, where even the most subtle changes can carry far-reaching consequences.

Among the many environmental factors that manpower planners must consider are economic constraints in the public and private sectors, demographic projections, Military standards, political and legal issues, and the

strategy that supports the Military's complex manpower structure. Although such interrelationships tend to complicate the learning of manpower research and analysis, certain statistical models are capable of assisting the manpower analyst by bringing together in a simplified, condensed form, the multifarious pieces of the entire personnel system. Indeed, effective management of human resources often requires the frequent use of statistical models for research and planning purposes. Of particular benefit to Military manpower analysts are those models that provide a probabilistic description of interrelationships among personnel end strengths, advancements, demotions, retirements, attrition, manning level inventories, and the anticipated or actual enactment of personnel policies. Such models enhance the continuous monitoring or projection of manpower personnel or training systems, and provide insight into environmental trends that may influence personnel management. Manpower models may also help the analyst anticipate the consequences of particular policy actions on force structure.

A. SCOPE AND OBJECTIVE OF THE THESIS

This thesis is based on the understanding that: (1) certain analytical skills are necessary for effective manpower management, and (2) these skills can be best developed and appreciated through practical experience and

the use of statistical models. However, it is also recognized that such practical or "hands on" application of available manpower models is probably not occurring at all of the relevant manpower policy or planning levels. Instead, some manpower managers rely on data and statistical analysis that emanate from costly, time-consuming methods, without ever applying or truly understanding fundamental modeling concepts.

The billet rotation policies of the Armed Services also tend to prohibit worthwhile exposure to the learning, reenforcement, or effective utilization of certain analytical skills. All too often, originality in analysis is repressed in favor of a "simply give me the answer" mentality. Limited appreciation of modeling concepts is even encouraged in some areas, as personnel administrators increasingly turn to private agencies for analytical support. This practice of using outside consultants and other specialists through contract support is necessary in the complicated area of manpower planning -- but an overreliance on other modelers or prefabricated research tools may eventually weaken the analytical skill of those assigned to manpower billets. In addition, individuals who already have weak analytical foundations may lose the motivation to become proficient in manpower system control strategy prior to rotation out of a manpower billet.

The major objective of this thesis is to demonstrate, and encourage, use of an inexpensive calculator as a "hands on" tool for planning and forecasting manpower levels and requirements. An original calculator software adaptation of fundamental Markov[1] theory is presented. The calculator software is designed for use by students, analysts, or by others who may simply desire to familiarize themselves with one particular aspect of manpower system management. For example, Enlisted Community Managers (ECMs), Officer Community Managers (OCMs), or other such persons concerned with annual end strenght projections, or manpower system manipulation should find this thesis useful.[2]

The thesis endeavors to demonstrate, in general terms, the intricate relationship between the Military's manpower management results and the various actions of defense manpower decisionmakers. Substantively, the focus is specifically on enlisted personnel. (Examples from the Navy are used to demonstrate the capability and application of the model used in this thesis.)

---

[1]A.A. Markov was a Russian born mathematician who developed the analytical technique in 1907.

[2]Nonetheless, it is emphasized that the thesis text was conceptualized and written basically for students who may ultimately occupy a manpower analysis billet.

Other objectives of the thesis are: (1) to provide a relatively uncomplicated analytical tool that facilitates understanding of manpower modeling concepts; (2) to strengthen the manpower student's comprehension of statistical modeling techniques and appreciation of manpower policy development; (3) to clarify and simplify the simulation or testing of theoretical resolutions to problems of manpower management (e.g., the quantity and quality of personnel to recruit or retain, and maintenance of adequate force structure); and (4) to foster an appreciation and understanding of the environmental uncertainties one must consider while ensuring paygrade manning levels accommodate total force end strenght. Environmental uncertainties include such things as technological advances, shifts in mission objectives, budget restrictions, changing national priorities, the economy, and policy actions at any of the various bureaucratic levels.

The following discussion is an abbreviated review of pertinent modeling concepts that should help readers to better understand the calculator software package developed in this paper. Specifically, the role of mathematical models is addressed, along with a brief explanation of the revelant modeling assumptions that are used. A concise discussion of Markov analysis is then presented, followed by a summary of the calculator software package itself.

(Students and analysts who are acquainted with basic mathematical modeling techniques may elect to proceed directly to the calculator software overview.)

B. MANPOWER MODELS AND BASIC MODELING ASSUMPTIONS

A manpower model is basically a mathematical description of how change takes place in a personnel system. The Markov chain model is addressed in this thesis, and is founded on implicit theories of hierarchical bureaucracies, with no direct consideration of exogenous variables (e.g., demographic trends or changing unemployment rates). This particular model helps simplify difficult concepts and problems of classification, aggregation, and statistical estimation.

The Markov chain model, as applied in the present context, requires specification and consideration of the constraints, or assumptions, under which manpower planners operate. Specific considerations may take the form of recruitment policy, total system size flexibility, economic factors, or the like. Additionally, the model requires specification of the mechanism that generates internal personnel flow (i.e., paygrade advancements). For example, some flows, such as promotion or demotion percentages, are under the direct control of manpower administrators and, therefore, are relatively straightforward. Other flows,

such as voluntary attrition rates, are not as straightforward [Ref. 1]. Thus, assumptions about future flow rates, or values, are likely to be based on a blend of historical data, analytical judgment, and intuition. In this regard, manpower models always incorporate two basic considerations about behavior of uncontrolled variables that are founded on "empirical" or "hypothetical" assumptions.

1. Empirical vs. Hypothetical Assumptions

An empirical assumption is one derived from past observation of the manpower system (e.g., paygrade attrition or advancement rates). It is usually assumed that the historical pattern observed will persist. In many planning situations, nonetheless, the analyst may be less interested in looking at the past than at the hypothetical assumptions by which he or she may explore a range of possible futures (e.g., seeking the answer to a variety of "what if...?" questions). In the case of manpower projections, it is often useful to evaluate the potential outcomes of employing different values for the system variables (e.g., different or varying paygrade attrition or promotion rates) because of the insight they give concerning the operation or direction of the entire system.

Other manpower system assumptions are also classified in various ways with respect to personnel flows. The four classifications of central importance to the thesis

are stochastic, deterministic, push, and pull. The differences between these classifications and their applicability are discussed below.

2. Stochastic vs. Deterministic Assumptions

> If one were to assume that EXACTLY 27 percent of the personnel in the E4 paygrade in the Navy would be discharged upon their end of active obligated service (EAOS) or prematurely during a given year, a DETERMINISTIC assumption about personnel flows would have been made. This implies that there is no random variation or uncertainty about how many E4s will actually leave during a given time interval [Ref. 1].
>
> If, on the other hand, one were to suppose that each individual in the E4 paygrade had a 27 percent PROBABILITY of leaving, one would be dealing with expected numbers of "leavers", and would have made what is considered a STOCHASTIC assumption [Ref. 1].

Manpower planning and personnel flow problems are more suitable for stochastic than deterministic treatment for two fundamental reasons. The first reason is that personnel questions must be examined in aggregate form. Since manpower management primarily relates to complex personnel structures -- with a need for the right numbers, in the right place, at the right time, and at the most economical cost -- statistical methods are often necessary to pull together an assortment of manpower components and thereby simplify evaluation of the larger manpower system. The second reason is the fact that the Military services operate in an uncertain environment, and one that is also complicated by the unpredictability of human behavior. Any

attempt to construct a theoritical base for manpower planning must confront this uncertainty through methods of statistical probability and prediction [Refs. 1;2].

3. Push vs. Pull Personnel Flow Assumptions

Manpower systems are further classified according to whether the impetus for a personnel flow or transition (e.g., advancement) lies at the starting-point or at the destination of the transition [Ref. 1]. For example, if a service member is promoted to a higher paygrade because it was NECESSARY TO FILL A VACANCY arising at a higher paygrade level, that individual may be viewed as being PULLED into the higher paygrade. However, if the promotion is AUTOMATIC, as a result of acquiring a new qualification (e.g., passing a paygrade advancement exam, meeting years of service requirements, completing personnel qualification standards, etc.) the transition is initiated because of an event that occurred at the point of origin. Such flows are called PUSH flows primarily because, once the qualifications have been achieved, the achieved qualification will "push" the individual out of his or her original paygrade into the next higher paygrade. Likewise, deviant behavior may push the individual to a lower paygrade (through demotion), or out of the system entirely (through discharge).

As previously indicated, this thesis is concerned with Markovian flows. However, it may now be stated more precisely that it is based on empirical or hypothetical, stochastic, supply-push flow assumptions, that are constrained primarily by recruitment policy, advancement opportunities or policy, historical attrition rates, total system size flexibility, specific paygrade manning levels, designated or desired personnel end strengths, and the interrelationships among all of these. The personnel system used here is assumed to be heterogeneous[3] and hierarchical[4] (in theory, if not always in practice.

C. THE FUNCTION OF MARKOV ANALYSIS

At the core of the Military's manpower structure are several major analytical instruments for manpower personnel analysis or policy. They contribute to the proper assessment and effective management of human resources, and enhance manpower system stability. One such instrument is a functional familiarity of the basic theory and application

---

[3]A system in which personnel may be classified by differing traits according to such things as paygrade, length of service, age, experience, etc. [Ref. 1].

[4]A true hierarchical system has no demotions or accelerated promotions whereby one may "skip" the next higher paygrade and proceed directly to a level two paygrades above the original paygrade (e.g., advancement from E4 to E6) [Ref. 1].

of mathematical models and their role with respect to effective manpower forecasting, planning, and system control. Markov analysis theory provides an excellent foundation for the statistical and mathematical modeling or management of personnel systems, and is thus a cornerstone for the comprehension of manpower system management.

Specifically, comprehensive and routine use of Markov analysis may help to clarify structural boundaries that the manpower planner or analyst must appreciate and operate within. Such boundaries consist typically of: (1) the maximum allowable number of personnel in the Armed Service(s); (2) the number and type of enlisted or officer paygrades necessary to meet Department of Defense (DoD) objectives; and, (3) the limitations imposed on internal personnel flows with regard to the recruitment into, movement within (i.e., promotion or demotion), or attrition from various paygrades. Markov analysis also helps one to focus on the impact of personnel policy changes with respect to annual, or steady state[5] manning levels. For example, routine execution of analysis could permit investigation of varying recruitment, training, or

---

[5]Steady state is a point in time at which the net effect of personnel inventories and advancements reflect no movement (no change); that is, the principal variables of recruitment, advancement, attrition, yearly beginning inventories, and annual end strenghts are all fairly stable (i.e., steady) and settled at some value [Ref. 3].

advancement policies. Such an investigation is useful for projecting the effects on a specific rating's paygrade advancement or attrition rates, or the potential impact on a Military Service's entire manpower structure.

D. GENERAL SCAMC OVERVIEW

SCAMC (pronounced "scam see") is a convenient abbreviation for Sapp's Calculator Adaptation of the Markov Chain model. It is the formal name of a calculator software package that employs the computational capabilities of a Texas Instruments handheld, programmable calculator. It is interactive, and will also tell the user "where to go" during each phase of data entry, program execution, or data retrieval. The software package incorporates a stochastic, supply-push, discrete-time Markov chain model. The model is driven by user-defined assumptions concerning available historical data, or anticipated or desired (i.e., hypothetical) data. Specifically, it predicts manpower end strenghts for seven categories of the Military's nine enlisted paygrades (i.e., a combined category for the three lowest paygrades of E1 through E3, and seperate categories for E4 through E9).

1. Manpower Forecasting, Planning, and Strategy

As indicated, this thesis offers a practical application of Markov analysis with respect to: (1) Military manpower forecasting; and, (2) Military

manpower planning. The following discussion is presented to reduce potential confusion in the fundamental definition and role of these two terms with respect to manpower and SCAMC.

a. Manpower Forecasting and Planning

The word "manpower" is borrowed from the discipline of economics and is similar in meaning to the word "labor", as used in the phrase, "land, labor, and capital" [Ref. 2]. Manpower forecasting is defined as the process of collecting and analyzing information to determine the future supply of, demand for, and management of any given skill or job category required to man the Military force. Much like weather forecasting, it depicts what will happen to a system "if present trends continue". By contrast, manpower planning may be defined as the process of developing policies and programs to achieve a desired balance between the supply of, and demand for, human resources. On this basis, of course, forecasting should precede planning [Ref. 1]. The primary purpose of Military manpower forecasting and planning is to prepare for the efficient employment, training, and development, as well as the proper utilization, of human resources.

b. Manpower System Control

SCAMC was developed for use in manpower forecasting and planning, and it devotes particular emphasis to the concept of manpower system control strategy

formulation. Within the context of manpower planning, a system control strategy reveals how one may modify system parameters, with respect to time and environmental constraints, so that a particular objective may be achieved. Unlike forecasting, where parameters are fixed and the goal is still undetermined, system control strategy formulation is characterized by a fixed goal and undetermined parameter values. A forecast is useful because it may alert policymakers to the need for action, but only system control theory can indicate how to modify or correct a situation [Ref. 2]. For example, control theory is useful in the investigation of potential manpower management policies for resolving a "petty officer shortfall in the Navy"; whereas a forecast will indicate what future "petty officer shortfalls" are inevitable if present policy is not modified.

2. General Role of SCAMC

In summary, SCAMC takes a straightforward approach and will provide a timely forecast of how the Military's manning structure is affected under a given set of user-defined assumptions or specific parameters.

As with any computer-generated answer based on user-defined assumptions, SCAMC's solutions are primarily intended to illuminate situations and serve as a guidepost. The ability to expedite otherwise fundamental and laborious

statistical calculations, however, should not be confused with an ability to produce "the" answer. The proper resolution of most manpower planning problems invariably requires a certain degree of interdisciplinary involvement, some subjective interpretations, recognition of the so-called practical element, and a large dose of solid, deductive reasoning.

II. SCAMC

> "Technological developments in computing hardware over the past decade have made computers available at very inexpensive prices. Among the available types are handheld programmable calculators, which today are capable of computational tasks surpassing those of larger computer systems of only a few years ago. The handheld programmable calculators are of such low cost that they are readily purchased by large segments of the academic, scientific, and business communities. They are so small in size that they are easily carried around by their users. Although designed for symbol manipulation, these "handhelds" are simply glamorous electronic arithmetic machines: They are microcomputers capable of solving advanced problems requiring functions and decision making."
>
> --M.D. WEIR

A. SCAMC BASICS

Sapp's Calculator Adaptation of the Markov Chain Model (SCAMC) is an original software program for Markov analysis that is fully user-interactive and designed for application on the Texas Instruments magnetic card, programmable model 59 handheld calculator (TI59). It may be used as a learning aid for the Markov chain model, or as an actual analytical tool for systematically evaluating Navy policies and their effects on manpower systems or requirements.

The program is not designed to be a substitute for the use of high-powered computers, or the convenience of

microcomputers. Rather, it is intended to serve as a functional supplement that expands the inventory of computational systems available to manpower students or Navy policy makers. It provides an opportunity for users to develop, or strengthen, a basic conceptual understanding of manpower systems with respect to Markovian flows by presenting and demonstrating its technique for an effective evaluation of manpower policy implications. For example, during periods of aggressive Military budget reductions, SCAMC is capable of providing timely and inexpensive insight into a range of hypothetical "what if...?" questions that directly affect present or future manpower policy or cost considerations. The program also allows users to be more adept and responsive to demands for effective policy formulation or analytical evaluation. Thus, it supports the analytical investigation of management, planning, programming, or budgeting policies.

SCAMC is completely integrated, and is introduced by this thesis. The thesis provides knowledge of basic manpower modeling theory, background, and assumptions. Instructions that familiarize the user with the necessary operating instructions, model execution procedures, and a general overview of the notation, terminology and methodology employed are also provided. The thesis text offers a general account of the theory of Markov chains so

that the modeling capability can be used by either the "seasoned" manpower analyst or novice student.

B. SCAMC HARDWARE

As noted above, SCAMC is written for use with a Texas Instruments, programmable (TI59), handheld calculator (Figure 1).

This particular calculator was selected primarily because it is relatively inexpensive, easy to understand and operate, and compact enough to fit in a pocket or briefcase. The convenient size of the calculator especially enhances the user's ability to provide timely and reasonable statistical information during meetings or classroom discussions. The TI59 calculator was also selected because it is routinely assigned to students in the Manpower Personnel and Training Analysis (MPTA) curriculum at the Naval Postgraduate School, and these students become familiar with its operation in a variety of courses.

It is also recognized that noncurriculum graduates may be assigned to manpower billets as a result of current billet rotation policy. This presentation consequently attempts to be simple and unemcumbered with technical information, so that those who are not familiar with the calculator or Markov modeling at the outset may learn enough to apply the program effectively.

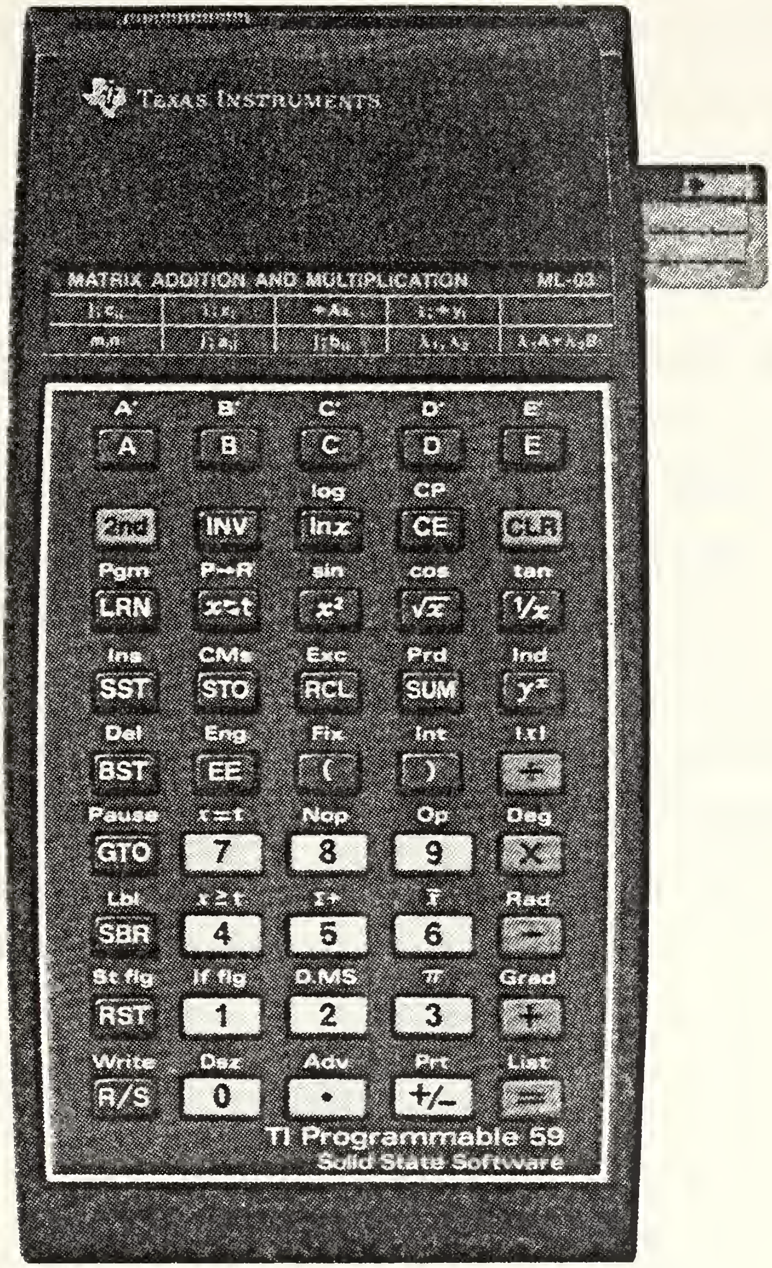

Figure 1. TI59 Handheld Calculator (actual size) with Magnetic Card Partially Inserted

C. PROGRAM DESCRIPTION

Manpower systems can be described in terms of the personnel inventories and movements (i.e., flows or paygrade advancements) with respect to time. SCAMC incorporates such a treatment, addressing the determination of manpower end strengths or requirements by paygrade (i.e., E1-E3, and E4 through E9). It uses a discrete-time Markov chain that is based on beginning or ending personnel inventories, paygrade recruitment proportion restrictions, attrition data, and a known stochastic matrix of internal personnel flows. Once available data have been manually entered into the calculator, it them may be manipulated to investigate the various policy effects of selected personnel strategies on the manpower system. The general relationship between SCAMC, beginning inventories, manpower policies, and end strengths is depicted in Figure 2.

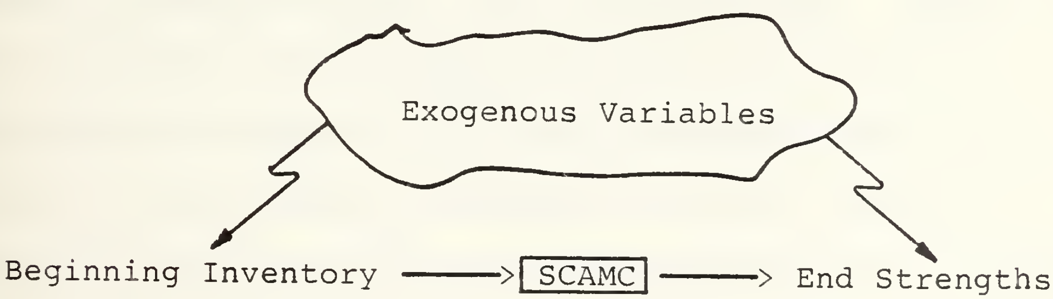

Figure 2. Role of SCAMC

As depicted above, SCAMC will help to forecast what will happen with respect to assumed trends or current policies. As such, it provides a guide to the analyst for the type of action required to achieve a desired manpower objective. All inputs are prompted by the calculator and simplified by use of a "SCAMC WORKSHEET" (Appendix A). Although some elementary familiarity with Markov analysis and TI59 operational characteristics would be helpful, it is neither assumed or required. (The reader is referred to References 1 or 2, and 3 for a more complete treatment of Markov analysis and TI59 operations, respectively.)

The program initially requires entry of: (1) the number of personnel recruited by paygrade; (2) the number of paygrade promotions or demotions; and (3) the personnel beginning inventories for each paygrade. When executed the program will first store, then manipulate, data entered as whole (i.e., raw) numbers into recruitment proportions, transition probabilities, and attrition rates. Second, it will calculate yearly ending personnel inventories by paygrade with respect to user defined assumptions (e.g., promotion opportunities, paygrade attrition, number of personnel recruited into various paygrades, etc.). Entered data may be reviewed at any time or permanently recorded on

blank magnetic cards[6] for subsequent manipulation or modification. This feature encourages "palm-of-the-hand" examination of a range of possible futures with regard to alternative manpower scenarios (i.e., changes in recruitment, transition probabilities, beginning inventories, or attrition).

D. SCAMC LOGIC

Typical program exeuction entails use of calculator magnetic cards 1 through 8 to create and record a transition probability matrix required by SCAMC and the Markov chain model. This matrix is then internally manipulated by the calculator to derive various annual end strengths, determine the recruitment necessary to achieve specified inventories, or permit analysis of policy impacts with regard to promotion or other manpower policies. Cards 1 through 8 are not required to be used if transitional probabilities are already known (e.g., pre-recorded on magnetic cards, or otherwise available for direct entry into the calculator). Thus, these cards are actually independent of SCAMC and need be executed sequentially only if raw data are available. Actual ending inventories are generated by use of magnetic card 9. This makes SCAMC essentially a one-card program.

---

[6]See Chapter III for discussion on proper use of magnetic cards.

When executed, SCAMC provides projected annual end strenghts with respect to user-defined constraints such as recruitment, promotion policy, historical attrition, and initial end strengths. SCAMC's interactive capabilities permit users to modify, control, or otherwise manipulate any of the above-mentioned constraints, thus allowing the existence of a "what if...?" capability that facilitates investigation of a wide range of manpower system control schemes. Conceivably, SCAMC is capable of providing insight to questions such as the following:

GIVEN THE FOLLOWING ASSUMPTIONS:

- 60,077 qualified personnel are recruited annually as E1-E3s;
- the Navy desires to "grow" a personnel inventory consisting of 80,000 E5s by the end of fiscal year (FY) 1988;
- historically, yearly attrition has been: (1) 19.2 percent for E1-E3s; (2) 27.0 percent for E4s; (3) 20.6 percent for E5s; and (4) 11.4 percent for E6s.
- FY 1981 promotion rates for all paygrades are assumed to remain constant through FY 1988 due to specified monetary restrictions; and
- FY 1980 beginning inventories for E1-E3s, E4s, and E5s are 147,991, 102,275, and 61,739 respectively.

ANSWER THE FOLLOWING:

(1) "Is the Navy capable of 'growing' enough E5s fast enough to meet requirements? If not, how long will it be before requirements are met? How could promotion policies be modified to assist the attainment of requirements within the prescribed time frame?"

(2) "What will happen if 4.25 percent more E4 personnel are advanced early to E5, or promotion rates for E5 and E6 are reduced by 8.0 percent in an effort to obtain the desired E5 end strength?"

(3) "What will be the impact on annual and future Navy end strength (e.g., through FY 1988) if either more or less E1-E3s are recruited annually in an effort to obtain the desired E5 manning level by FY 1988?"

Execution or expansion of SCAMC's "what if...?" analytical capability may prove beneficial when investigating potential resolutions to manpower system questions. As such, it may encourage the user to consider other impacts on the entire manpower system under investigation in lieu of limited paygrade evaluation or analysis (i.e., that which is focused on a single paygrade and fails to consider the effects of recommended policy on other paygrades).

III. SCAMC SOFTWARE

The only way to discover the limits of
of the possible is to go beyond
them into the impossible.

--Clark's second law

A. GENERAL DISCUSSION

SCAMC is written in machine language on a total of nine magnetic computer cards, and consists of 1538 sequential program steps and internal repartitioning for 89 short-term, internal memory storage registers. Program instructions consist of a series of base ten numbers which are converted internally by the calculator into binary digits recognizable by circuits which control the interpretation and execution of instructions. The program logic is organized in modular fashion (i.e., in logical sub-packages which can be individually programmed, debugged and validated). SCAMC has three program modules, each having its own series of subroutines. Once users comprehend and feel comfortable with SCAMC's treatment of Markov analysis, they will simply have to identify the situation for which analysis is desired, "read"[7] the appropriate magnetic card into the calculator, activate calculations, and then analyze results

[7] See the section III.B, "MAGNETIC CARDS", for explaination and use of this term.

or experiment with various manpower policy scenarios as desired. The title and abbreviated function of each magnetic card are as follows:

CARD	TITLE	FUNCTION
1&2	DATA ENTRY	Allows for the entry of recruitment, internal flow and beginning inventory data.
3&4	RECORD DATA	"RECORD DATA" is not actually a module, per se, it simply records data entered via the "DATA ENTRY" card onto two blank magnetic cards which are inserted by the user.
5&6	TRANSITION CALCULATION	Calculates and stores transition probabilities, recruitment proportions and attrition rates for later calculations.
7&8	RECORD TRANSITIONS	Same as "RECORD DATA" but for the probabilities calculated via the "TRANSITION CALCULATION" module.
9	YEARLY ENDING INVENTORY	Calculates the yearly ending inventory. "Yearly ending inventory" is the MOST VITAL MAGNETIC CARD as it projects future inventories, calculates required recruitment to meet accession requirements necessary to achieve desired end strengths, determines beginning inventories, if they are not known, and calculates personnel attrition or internal flows. Magnetic card 9 has the capability to determine inventories for any number of periods selected by the user, and permits examination of policy effects on end strengths over time.

B. MAGNETIC CARDS

Throughout execution of SCAMC it is necessary for users to "read" the above magnetic cards into the calculator, or

"write" information from the calculator's internal, short-term memory storage registers onto blank magnetic cards (Figure 3). Hence, the following discussion is presented.

1. Reading or Writing Magnetic Cards

As discussed earlier, SCAMC is merely a series of calculator modules (i.e., programs) recorded onto magnetic cards and arranged in a logical sequence. "Reading" is the term that reflects how the calculator's internal short-term memory recognizes and stores pre-recorded calculations, or solutions, that have been previously recorded onto a magnetic card. Reading is accomplished by inserting a magnetic card, containing pre-recorded programming information on it, into the read-write slot that is located on the upper right side of the calculator (Figure 4). On the other hand, if the recording of information already stored in the calculator's short-term memory is desired, a "Write" command may be issued. The write command will direct the calculator to electronically transfer (i.e., electronically "write") information from its internal memory onto a magnetic card that the user inserts into the TI59. The procedure for reading and writing is essentially the same. The only exception is that reading transfers information TO the calculator, whereas writing receives information FROM the calculator.

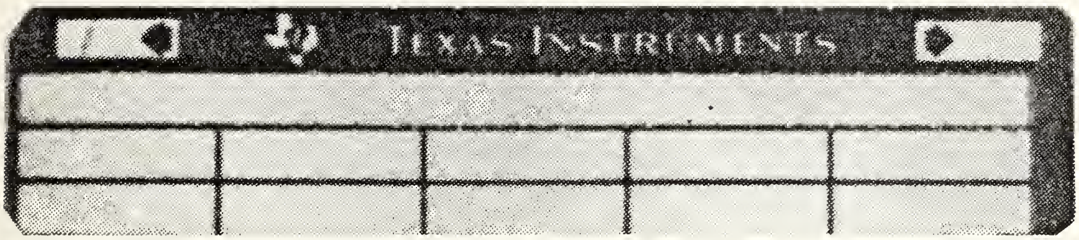

Figure 3. Calculator Magnetic Card
[Ref. 4]

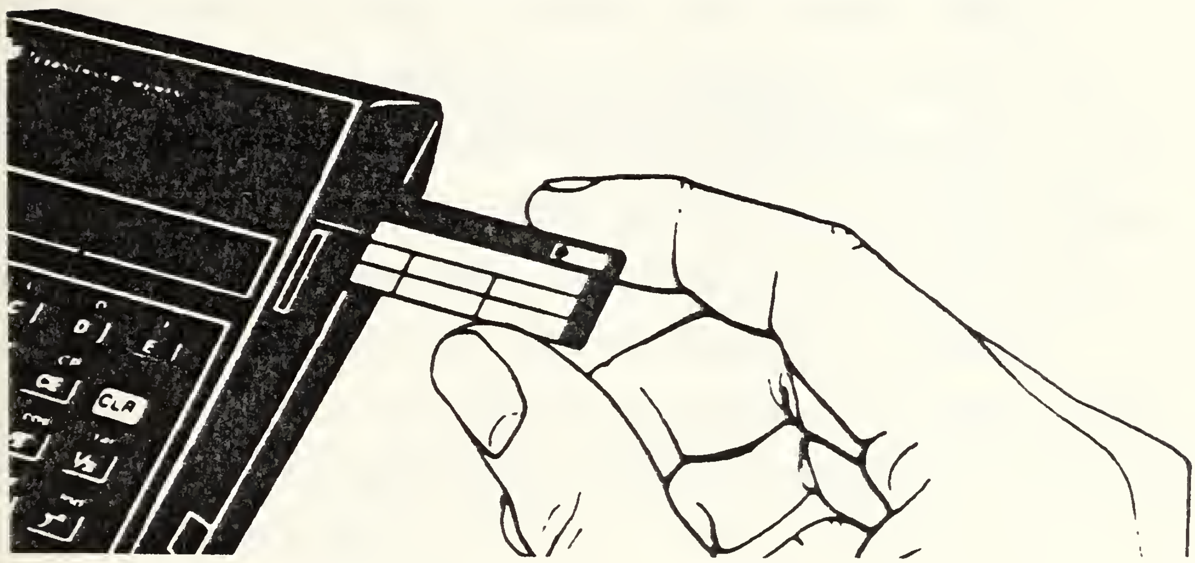

Figure 4. Inserting Magnetic Card into Read-Write Slot
[Ref. 4]

The "reading" or "writing" of program information from or onto a magnetic card is possible because it is coated with magnetizable ferrous oxide similar to that used on standard cassette recording tapes.

2. Card Sets and Card Tracks

With the exception of card 9, all magnetic cards used by SCAMC are organized in sets of two (i.e., cards 1 and 2, cards 3 and 4, etc.). No single card in a set can function independently of its "mate". Thus, each card of a set depends on the other to effect designated calculations for which they are programmed. Each magnetic card is divided into two tracks, an UPPER, and a LOWER. (These tracks are commonly referred to as "sides".) A set of two cards constitutes a combined total of four tracks (i.e., two upper and two lower). The LOWER track of any card is always represented by odd numbers. Therefore, given a set of two cards, the lower track of a set of cards will always be numbered as track 1, or track 3. Likewise, the UPPER tracks of the same set of cards will always be numbered as track 2, or track 4 (see Figure 5).

3. How to Read from Magnetic Cards

To "read" a magnetic card, the user must first key (i.e., press on the calculator keyboard) the number of the side that he or she desires to be read into the calculator's memory. This number will either be a 1, 2, 3, or 4.

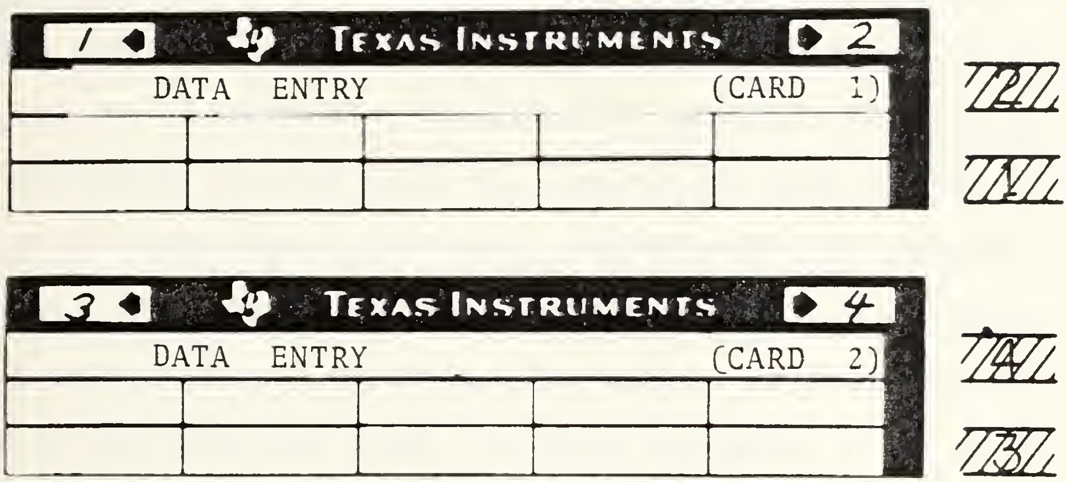

Figure 5. Upper and Lower Tracks of One Set of Magnetic Cards [Ref. 4]

The USER INSTRUCTIONS WILL ALWAYS INDICATE WHICH NUMBER IS TO BE KEYED PRIOR TO INSERTING A CARD INTO THE CALCULATOR. For example, to read track 1 (i.e., to read the lower track of a card) the user should: (1) key a "1" on the keyboard, then (2) insert the card (RIGHT SIDE UP) into the calculator's read-write slot located on the right side of the calculator. Insertion of the magnetic card will activate a calculator drive motor to pull the card over a magnetic head that automatically reads and then records program and memory information from that card's LOWEST track (i.e., track 1) into the calculator's memory. The card is then partially ejected from the read-write slot on the left side of the calculator, and must subsequently be removed by the user. Once the card is partially ejected, a number will appear in the calculator's display window to indicate which track of the card was read. In this instance, a "1" should appear in the calculator's visual display[8] [Ref. 4].

The above procedure is identical for reading track 3, except a "3" must be keyed first. Likewise, it also applies for reading tracks 2 or 4 of a magnetic card, except that the card MUST BE INSERTED UPSIDE DOWN! Such an insertion is necessary because the calculator's magnetic

---

[8] If a number different from that initially keyed in is showing, or the display is blinking, reinitiate the read procedure.

head will only read the LOWEST track relative to how the card was inserted (see Figures 6 and 7).

4. How to Write onto Magnetic Cards

To record information onto a magnetic card, the user simply follows a procedure similar to that for reading. However, he or she must first indicate that a reverse procedure is desired; that is, that data are to be transferred FROM the calculator's internal memory and "written" onto a magnetic card. This is accomplished by keying "2ND" "WRITE" after a track on which to store information has been indicated. For example, to write onto a lower track, say track 1, the user will sequentially key: "1", "2ND", "WRITE"; then insert the card (RIGHT SIDE UP) into the read-write slot. To write information on track 2 or 4 of a card, the user will key: "2" (or 4), "2ND", "WRITE"; then insert the card (UPSIDE DOWN) into the read-write slot. (SCAMC user instructions will always inform the user what to key prior to writing information onto a card.)

C. BLINKING INDICATORS AND PROMPTER CODES

Use of the software package has been simplified by a series of "blinking indicator displays" and "prompter codes." A blinking indicator is typically a two-digit number that will normally blink for approximately three seconds. Its purpose is to indicate what row or column of

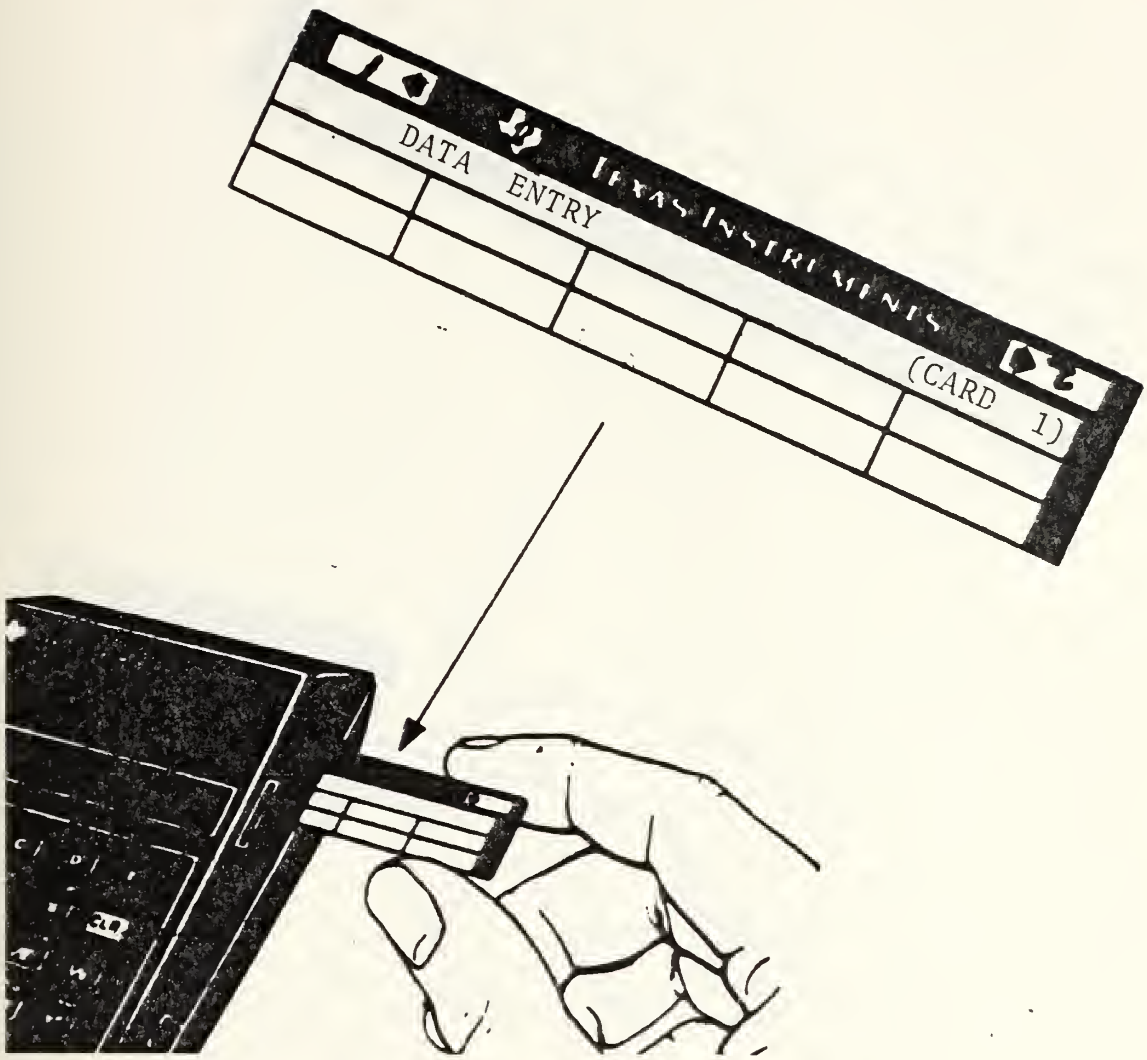

Figure 6. Reading Data from Track 1 of a Magnetic Card into Calculator Memory [Ref. 4]

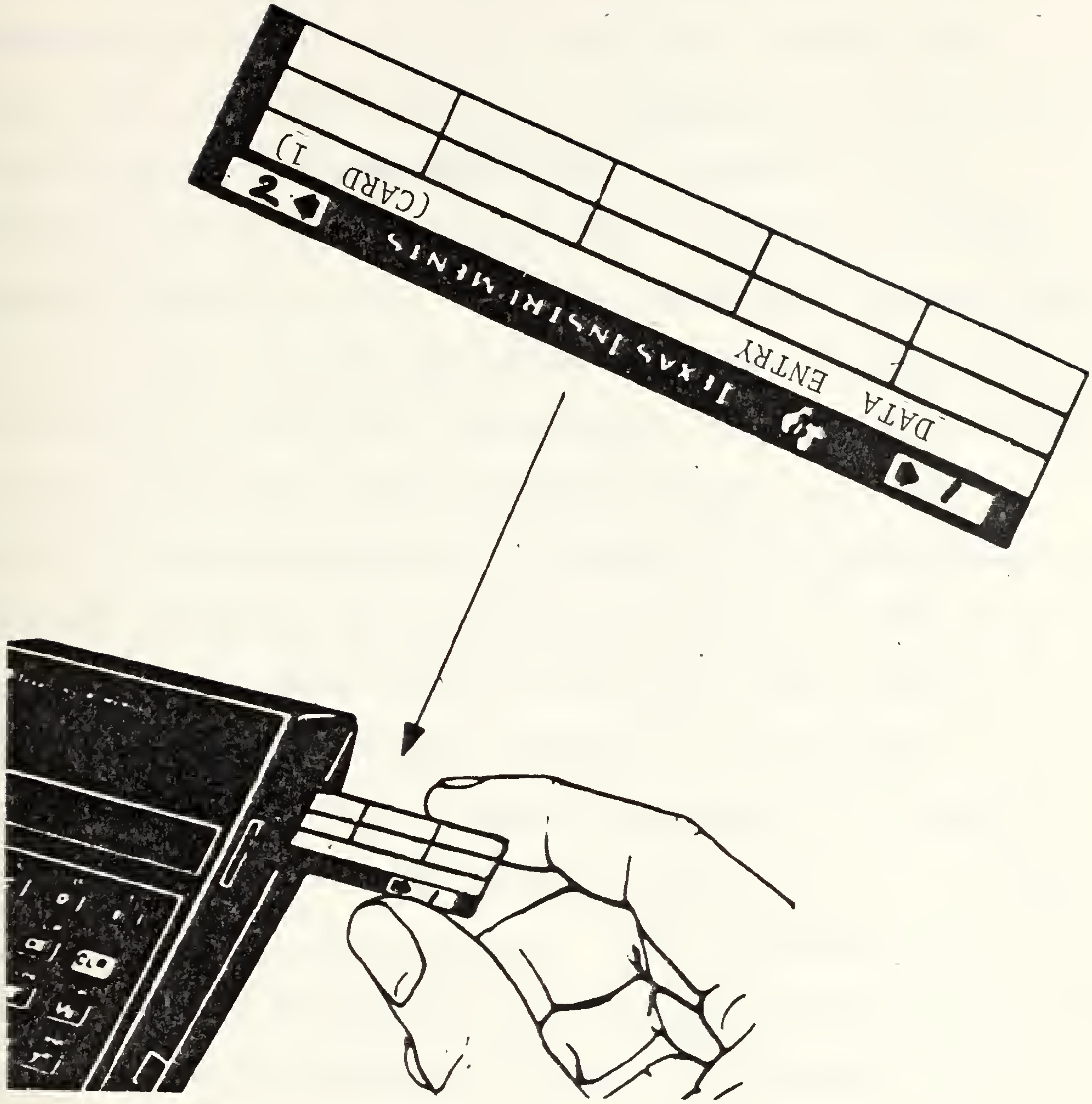

Figure 7. Reading Data from Track 2 of a Magnetic Card into Calculator Memory [Ref. 4]

data is to be entered into the calculator next. For example, a blinking "21" indicates the user is to enter data commencing with row 2, cell 1 (see below example and Figure 8). A prompter code is a single digit shown in the visual display and does not blink. A prompter code prompts entry of data from a specific cell on the SCAMC WORKSHEET (Appendix A). A prompter code will always remain in the visual display until another number is keyed into the calculator by the user. For example, if subsequent to the blinking indicator "21" the display clears and a "1" appears, the calculator may be thought of as indicating: "You may now enter data commencing with row 2, cell 1, (short pause[9]), enter data for cell 1 at this time". Another "blinking indicator display" is the number "9.9999999 99"[10]. This indicates all data for a given row (i.e., paygrade) such as categories 1, 2, ..., 7 have been accepted by the calculator. The "9.9999999 99" is always followed by another two digit non-blinking indicator that serves as a "heads-up" to users as to which row of

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[9]A "short pause" is typically a period of approximately one to seven seconds during which the calculator visual display window is clear while a subroutine is being executed. A "long pause" is similar, however, lasting anywhere from 15 to 80 seconds. A short pause is represented by "p" on the user instructions, where as a long pause by "pp".

[10]Indicated as "9.999 99" on the SCAMC user instructions.

information is to be entered next. Once the calculator has been reinitiated for receiving a new row of data (i.e., subsequent to the user keying "B" at step 6.B.) a blinking indicator will once again appear and be followed by a prompter code. The following example is taken from step 6.a. through 6.b. on the SCAMC USER INSTRUCTIONS (Appendix B). Each figure (i.e., Figures 8 through 14) represents one specific step and illustrates the blinking display and prompter codes for the E1-E3 paygrade.

FROM THIS POINT FORWARD, THE PROCEDURE IS RECURSIVE UNTIL DATA FROM ALL SEVEN ROWNS HAVE BEEN ENTERED. At that time, the calculator will inform the user of this fact by flashing "9.9999999 99p81". Since there is no 8th row of data available for entry, the "81" indicates that the user is through with data entry for this particular step. "81" is used consistantly throughout SCAMC as a back-up indicator to remind users that data entry for all rows has been completed and it is time to proceed to step 7 (i.e., reading card 5).

Detailed explanation of the modules or calculator nmtation is not within the scope of this paper. For now, the user may choose to ignore the "blinking indicator displays" or "prompter codes" that periodically appear in

STEP	PROCEDURE	REASON
6.A	USER PRESSES A'	Initalizes the calculator to receive data for E1-E3 personnel.
6.A	DISPLAY BLINKS THE INDICATOR "11"	Indicator informs the user data entry is to commence with data from row 1, cell 1 on the SCAMC user worksheet.

Figure 8. Step 6.A

STEP	PROCEDURE	REASON
6.A.1	DISPLAY CLEARS, THEN DISPLAYS A "1"	This action is represented by the notation "11p1" (i.e., shows a "11"), clears, then shows a "1". The 1 is a prompter code prompting entry of data from cell 1 of row 1. That cell is indicated on the worksheet by "n(1,1)."
6.A.1	USER ENTERS DATA FROM CELL n(1,1)	N.A.*
6.A.1	USER KEYS "RUN/STOP" (R/S)	Activates necessary sub-routine to identify, process, and store entered data.
6.A.1	A "2" APPEARS IN THE DISPLAY	The "2" is a prompter code that is prompting entry of data from cell 2 (of row 1). This cell is designated as "n(1,2)" on the worksheet.

* N.A. - Not applicable

Figure 9. Step 6.A.1

STEP	PROCEDURE	REASON
6.A.2	USER ENTERS DATA FROM CELL n(1,2)	N.A.
6.A.2	USER KEYS R/S	This action activates the necessary sub-routines to identify, process, and store the entered data.
6.A.2	A "3" APPEARS IN THE DISPLAY	The "3" is a prompter code which is prompting entry of data from cell 3 of row 1. This cell is designated as "n(1,3)" on the worksheet.

Figure 10. Step 6.A.2

STEP	PROCEDURE	REASON
6.A.3	USER ENTERS DATA FROM CELL n(1,3)	N.A.
6.A.3	USER PRESSES R/S	This action activates the necessary sub-routines to identify, process, and store the entered data.

Figure 11. Step 6.A.3

STEP	PROCEDURE	REASON
N.A.	USER CONTINUES TO ENTER DATA FROM ROW 1 CELLS AS PROMPTED BY THE CALCULATOR	Enter data for remainder of E1-E3s paygrade.

Figure 12. Steps 6.A.4 through 6.A.8

STEP	PROCEDURE	REASON
6.A.9	DATA FOR ROW 1 COMPLETELY ENTERED, USER KEYS R/S	A "9.9999999 99" will blink for approximately one-half of one second indicating all the data for row 1 has been accepted, processed, and stored by the calculator. The display then blinks a "21". (The above sequence is represented by the notation "9.99 99p21". The 21 is a "heads-up" for users and indicates he or she is to continue with data entry continuing from row 2, cell 1 (i.e., E4s). NOTE: The calculator must be initialized to receive data for the E-4 personnel prior to continuing data entry.

Figure 13. Step 6.A.9

STEP	PROCEDURE	REASON
6.B	USER INITIALIZE CALCULATOR TO RECEIVE DATA COMMENCING FROM CELL n(2,1), KEY "B"	This action initializes the calculator to receive data for E-4 personnel.

Figure 14. Step 6.B

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
6.A	E1-E3	Initialize calculator for data entry commencing from row 1, cell 1	N.A.	2ndA'	11pl
6.A.1		Enter data from cell n11	n(11)	R/S	2
6.A.2		Enter data from cell n12	n(12)	"	3
ETC.		ETC.	ETC.	ETC.	ETC.
. . .		. . .	. . .	. . .	. . .
6.A.9		Enter data from	n(19)	"	9.99 99p31

GRADE	E1-E3 Column 1	E4 Column 2	E5 Column 3	E6 Column 4	E7 Column 5	E8 Column 6	E9 Column 7		
RECRUIT DATA (ROW 0)	CELL n01 ( )	CELL n02 ( )	CELL n03 ( )	CELL n04 ( )	CELL n05 ( )	CELL n06 ( )	CELL n07 ( )	ATTRITION Column 8	BEG. INV. Column 9
E1-E3 (ROW 1)	CELL n11 ( )	CELL n12 ( )	CELL n13 ( )	CELL n14 ( )	CELL n15 ( )	CELL n16 ( )	CELL n17 ( )	CELL n18 ( )	CELL n19 ( )
E4 (ROW 2)	CELL n21 ( )	CELL n22 ( )	CELL n23 ( )	CELL n24 ( )	CELL n25 ( )	CELL n26 ( )	CELL N27 ( )	CELL n28 ( )	CELL n29 ( )
E5 (ROW 3)	CELL n31 ( )	CELL n32 (	CELL n33	CELL n34)	CELL n35 ( )	CELL n36 ( )	CELL n37 (	CELL n38	CELL n39 ( )
					n45	CELL n4			

The above represents page one of a SCAMC worksheet.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
6.B	E4	Initialize calculator for data entry commencing from row 1, cell 1	N.A.	B	21pl
6.B.1		Enter data from cell n21	n(21)	R/S	2
. . .		. . .		. . .	
6.B.9		Enter data from cell n29	n(29)	"	9.99 99p31

Figure 15. Illustration of Flashing Indicators and Prompter Codes for Steps 6.A Through 6.B.9

the calculator display. If user instructions are followed, SCAMC will be properly executed and the stage is set for effective manpower analysis.

IV. NOTATION, TERMINOLOGY AND METHODOLOGY

"Any simple idea will be worded
in the most complicated way".

--Malek's law

A. PAYGRADE CATEGORIES

SCAMC considers the Military's enlisted grade structure as a dynamic system consisting of personnel inventories, recruitment, and internal flows between categories. These categories are organized by subgroups that are based on enlisted ratings, length of service or other such relevant attributes. The program has the capability to categorize or classify personnel with respect to any user-specified attributes. However, for this paper, it categorizes personnel solely with respect to enlisted paygrades such as E1-E3, E4, E5, E6, E7, E8, and E9. Specifically, the enlisted paygrade structure (and civilian status points) is categorized as follows:

CIVILIAN

(Preenlistment or Nonenlistment) = Category Ø

MILITARY

Paygrade E1-E3 = Category 1
Paygrade E4 = Category 2
Paygrade E5 = Category 3
Paygrade E6 = Category 4
Paygrade E7 = Category 5
Paygrade E8 = Category 6
Paygrade E9 = Category 7

CIVILIAN

(Postenlistment)[11] = Category 8

The total number of active duty Military categories (i.e., paygrades) is denoted by the letter "k". Thus, for SCAMC, k will always equal 7. The categories themselves are indicated by the subscripts "i" or "j"; and the number of personnel in a category is indicated by a lower case "n".

B. INTERNAL PERSONNEL FLOWS

The number of personnel that "flow" (i.e., those who are promoted between categories of paygrades, such as from category i to category j) is considered an internal flow. The notation "n(i,j)", (pronounced "n sub i,j"), denoted the number of personnel (n) originally in category i who ultimately flowed (i.e., were promoted) to category j. The "n" number of personnel promoted from paygrade E4 to paygrade E5 is denoted as "n(4,5)." For example, in considering the enlisted paygrade structure shown above, the following observations may be made:

---"n(1,2)" indicates the number of personnel who were promoted from category 1 (E1-E3) into category 2 (E4).

---

[11]Civilians in this category include all persons who have been discharged under any condition from the Armed Services.

---Likewise, "n(4,5)" indicates the number of personnel who were promoted from category 4 (E6) into category 5 (E7).

---More specifically, "4,976(4,5)" denotes that 4,976 enlisted personnel were promoted from E6 to E7; "1,533(5,6)" denotes that 1,533 E7s were promoted to E8.

Internal flows may also indicate demotions or non-promotions. For example:

---"32,446(4,4)" denotes that 32,446 E6s were not promoted: that is, 32,446 E6s were "promoted" from E6 to E6, "n(i,i)".

---"163(4,3)" denotes that 163 E6s were demoted to E5, "n(i,i-1)".

---"Ø(4,6)" denotes that Ø (i.e., zero) E6s were promoted early to E8, "n(i,j+1)".

C. TIME

Manpower planning is accomplished in a dynamic environment. Therefore, all SCAMC calculations are made with respect to user-specified time intervals. Typically, a one-year period or timeline is used where the interval is either a calendar or fiscal year. A lower case "t" indicates the end of a period, and "t-1" indicates the beginning of a period. Graphically, the time line appears as illustrated in Figure 16.

```
               (start)                    (end)
"(t-1,t)" = |<------- 1 year ------->|
               (t-1)                      (t)
```

For example: to indicate the interval of time between 1980 and 1981, the time line would appear as shown below:

```
(1980,1981) = |<------- FY80 ------->|
           1980<------- (T-1) ------->1981
```

Figure 16. Illustration of Time Line/Interval

Capital "T" minus 1, "(T-1)", is used for brevity to indicate an interval of time in lieu of the notation, "(t-1,t)". For example, one may denote a period of time by using "(t-1,t)" where t-1 equals the year 1980, and t equals the year 1981, by the notation "(1980,1981)". For brevity, the same period of time may be indicated by using "(T-1)". Thus, "T-1)", as denoted by (1980), represents the period of time from the beginning of 1980 to the beginning of 1981.

The notation "(T-1)" is preferred when indicating internal flows with respect to time. Thus:

---n(1,2)(T-1), where (T-1) equals 1980 denotes the number of personnel who were promoted from category 1 into category 2 during the period of time between 1980 and 1981.

---More specifically, n(i,j)(T-1) where: n=4,976; i=4; j=5; (T-1)=1980; would appear as "4,976(45)(1980)", and denotes 4,976 E6s were promoted to the grade of E7 during the period between the years of 1980 and 1981.

---Likewise, n(i,j)(T-1) where: n=564; i=6; j=7; (T-1)=1981; would appear as "564(67)(1981)", and denotes 564 E8s were promoted to the grade of E9 during the period between the years of 1981 and 1982.

D. INTERNAL PERSONNEL FLOW MATRIX

Internal flows are commonly organized into a square matrix to enhance clarity. The internal flow matrix utilized by SCAMC, and therefore by the user, is illustrated in Figure 17.

	E1-E3	E4, etc...,	E9
E1-E3	n(1,1)(T-1)	n(1,2)(T-1)...,	n(1,7)(T-1)
E4	n(2,1)(T-1)	n(2,2)(T-1)...,	n(2,7)(T-1)
(etc)	(etc)...,	(etc)...,	(etc)
"	"	"	"
E9	n(7,1)(T-1)	n(7,2)(T-1)...,	n(7,7)(T-1)

Figure 17. N Matrix, "N=(nij)"

The above matrix is conventionally referred to as the "N MATRIX"[12].

E. ATTRITION

Attrition from the system (e.g., from the matrix or particular military service) is indicated by a notation which is similar to that for internal flows. However, one who "leaves", regardless of the reason (e.g., voluntary

[12] In practice, many of the internal flows will have zero entries because it is highly uncommon for, say, an E1-E3 to be promoted to the grade of E9, or an E9 to be demoted to E1-E3 during any one-year period.

separation, death, etc.) is considered as having "flowed" (e.g., "left") from the Military system's highest category (i.e., exit the highest category) and flowed into another civilian system category. Therefore, the civilian category into which one flows is considered to be at least one level higher than the highest possible Military category (recall that k represents the highest enlisted category possible, therefore, k=7). Thus, attrition may be indicated by k+1.

> ---Thus, "n(ik+1)(T-1)", where n=22,748; i=2; k=7; and T-1=1980, appears as "22,748(28)(1980)" and denotes, "22,748 E4s left the Military (i.e., category 2) during the year between 1980 and 1981"; that is, 22,748 E4s exceeded the "k th" category, and, therefore, left the Military's Manpower system.

SCAMC "attaches" attrition to the N MATRIX so that the user may witness the promotions and attrition for all grades at a glance. The result is an N MATRIX that appears as shown in Figure 18.

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx			ATTRITION
n(1,1)(T-1)	n(1,2)(T-1)...,	n(1,7)(T-1)	n(1,8)(T-1)
n(2,1)(T-1)	n(2,2)(T-1)...,	n(2,7)(T-1)	n(2,8)(T-1)
(etc)...,	(etc)...,	(etc)	(etc)
"	"	"	"
n(7,1)(T-1)	n(7,2)(T-1)...,	n(7,7)(T-1)	n(7,8)(T-1)

Figure 18. N Matrix with Attrition Shown

F. BEGINNING AND ENDING INVENTORIES

The initial number of personnel within a category are referred to as the category's "inventory" or "stock."[13] Beginning inventories are indicated in a manner similar to internal flows. However, flows relate to an INTERVAL of time, (t-1,t) or (T-1), whereas inventories relate to a SPECIFIC point in time, (t-1) or (t); that is, beginning inventory and ending inventory (i.e., end strength). Thus, although both internal flows and beginning or ending inventories relate to a specific category (1, 2, 3,..., 7), internal flows are continuous, with respect to time, and inventory data are discrete. Additionally, since no "flow" or "promotion" is implied for an inventory, the subscript "j" is not necessary. One may also think of an inventory as a "snap-shot" of a given category at a particular point in time (i.e., at the beginning of the year, "t-1"), or at the end of the year ("t"). Hence:

> ---the notation, "n(i)(t-1)"; where n=102,275; i=2; and (t-1)=1980; appears as "102,275(2)(1980)", and denotes 102,275 personnel were in the paygrade of E4 at the beginning of 1980.

---

[13]The term "inventory" is preferred and is used throughout this paper. However, the terms inventory and stock are interchangeable.

---Likewise, "n(i)(t)"; where n=76,668; i=2; and (t)=1981; appears as "76,668(2)(1981)", and denotes 76,668 personnel where in the paygrade of E4 at the end of 1981[14].

As with attrition, SCAMC "attaches" the beginning and ending inventories for each grade to the N MATRIX. Beginning inventories are recorded in a column to the right of ATTRITION, and ending inventories are placed in a row beneath the INTERNAL FLOW row for E9's. Figure 19 illustrates the N Matrix subsequent to the addition of beginning and ending inventories.

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx			ATTRITION	BEG. INV.
n(11)(T-1)	n(12)(T-1)...,	n(17)(T-1)	n(18)(T-1)	n(1)(t-1)
n(21)(T-1)	n(22)(T-1)...,	n(27)(T-1)	n(28)(T-1)	n(2)(t-1)
(etc)...,	(etc)...,	(etc)	(etc)	(etc)
"	"	"	"	"
n(71)(T-1)	n(72)(T-1)...,	n(77)(T-1)	n(78)(T-1)	n(7)(t-1)
n(i)(t)	n(2)(t)...,	n(7)(t)	<— ENDING INVENTORY	

Figure 19. N Matrix with Attrition, Beginning and Ending Inventories

[14]The end of a period may vary. For instance, the end of the U.S. government fiscal year is currently the last day of September, whereas the end of the Gregorian calendar year is the last day of December.

G. RECRUITMENT

"n(Øi)(t)" indicates the number of personnel recruited from the civilian pool of people eligible for Military service into category i during the period (T-1) (e.g., during FY 1981). Recruitment is thought of as taking place after promotion and attrition for the "i th" category having occurred. Therefore, "(t)" is conventionally used in place of "(T-1)" to indicate the specific time (i.e., the beginning or end of a year) during which category i recruitment occurred. Although recruitment actually occurs during the period from (t-1) to (t), it is convenient to use the notation "(t)", (i.e., end of a time interval) since it emphasizes the ordering of events [Refs. 1;2]. It may be helpful to think of a situation where the analyst will not receive data indicating the number of enlisted accessions required to fill vacancies until AFTER promotion, attrition, Military personnel demand, or other such figures have been finalized. Such information is typically available in summary form subsequent to the end of a period (e.g., the end of the fiscal year). The subscripts "Ø" (zero), and "i", represent the flow from the preenlistment or nonenlistment civilian category (i.e., category zero) into category i (i.e., induction into the Military as an E1, E2, or E3). That is, a civilian is not thought of as being in an enlisted paygrade category PRIOR to his or her enlistment.

Therefore, it is proper to assume that the individual belongs to a non-category relative to the Military's enlisted paygrade structure. Since category 1 is the lowest possible enlisted category to which an enlisted member may belong, it is logical to consider that the category from which a civilian would typically come from, with respect to the Armed Service's seven paygrades categorizations, would accordingly be titled the "ZERO" category. Hence, "n(Øi)(t) where; n=6Ø,Ø77; i=1; and t=198Ø, would appear as "6Ø,Ø77(Ø1)(198Ø)" and denotes 6Ø,Ø77 people were recruited into the Military system as E1-E3's during the period between 198Ø and 1981[15].

As with attrition and beginning and ending inventories, recruitment may also be added to the N MATRIX. These data are the last to be added to the N MATRIX. With the addition of attrition, beginning and ending inventories, and recruitment data, the N MATRIX is transformed into a table and it is no longer proper to refer to this table of information as the N MATRIX. Therefore, the table is titled as the "YEARLY GRADE TABLE"[16] and it is the basis of the

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[15] In a hierarchical system (such as the Armed Services), recruitment typically occurs at the lowest level, unless lateral entry is permitted.

[16] The yearly grade table should not be confused with "time in grade".

SCAMC worksheet (Appendix A). This table of information permits analysis of the system with respect to periods of time which are commonly defined on yearly (i.e, Fiscal Year) intervals. The YEARLY GRADE TABLE is shown in Figure 20. An example of the SCAMC worksheet is shown in Figure 21.

The YEARLY GRADE TABLE permits examination of the major factors that define the Armed Service's enlisted pay structure. By utilizing the table, one may easily determine:

(1) The number of personnel recruited into a grade;

(2) The number of promotions, demotions or non-promotions;

(3) The number of individuals who leave the Military;

(4) The beginning or ending inventories of the system with respect to a base year through steady state; and

(5) Other relevant data as determined or desired by the user.

H. TRANSITION PROBABILITIES

It is frequently more informative for the analyst to express promotions and attrition per grade level as a proportion of that paygrade's personnel inventory in lieu of raw numbers. For example, given a 1980 E1-E3 beginning

n(01)(t)	n(02)(t)...,	n(03)(t)	<—— RECRUITMENT	
xxxxxxxxxx	xxxxxxxxxxxxxx	xxxxxxxxxx	ATTRITION	BEG. INV.
n(11)(T-1) n(21)(T-1) (etc)..., " n(71)(T-1)	n(12)(T-1)..., n(22)(T-1)..., (etc)..., " n(72)(T-1)...,	n(17)(T-1) n(27)(T-1) (etc)..., " n(77)(T-1)	n(18)(T-1) n(28)(T-1) (etc)..., " n(78)(T-1)	n(1)(T-1) n(2)(T-1) (etc) " n(7)(T-1)
n(1)(t)	n(2)(t)...,	n(7)(t)	<—— ENDING INVENTORY	

Figure 20. Yearly Grade Table

GRADE	E1-E3 Column 1	E4 Column 2	E5 Column 3	E6 Column 4	E7 Column 5	E8 Column 6	E9 Column 7		
RECRUIT DATA (ROW 0)	CELL n01 ( )	CELL n02 ( )	CELL n03 ( )	CELL n04 ( )	CELL n05 ( )	CELL n06 ( )	CELL n07 ( )	ATTRITION Column 8	BEG. INV. Column 9
E1-E3 (ROW 1)	CELL n11 ( )	CELL n12 ( )	CELL n13 ( )	CELL n14 ( )	CELL n15 ( )	CELL n16 ( )	CELL n17 ( )	CELL n18 ( )	CELL n19
E4 (ROW 2)	CELL n21 ( )	CELL n22 ( )	CELL n23 ( )	CELL n24 ( )	CELL n25 ( )	CELL n26 ( )	CELL N27 ( )	CELL n28 ( )	CELL n29
E5 (ROW 3)	CELL n31 ( )	CELL n32 ( )	CELL n33 ( )	CELL n34 ( )	CELL n35 ( )	CELL n36 ( )	CELL n37 ( )	CELL n38 ( )	CELL n39
E6 (ROW 4)	CELL n41 ( )	CELL n42 ( )	CELL n43 ( )	CELL n44 ( )	CELL n45 ( )	CELL n46 ( )	CELL n47 ( )	CELL n48 ( )	CELL n49
E7 (ROW 5)	CELL n51 ( )	CELL n52 ( )	CELL n53 ( )	CELL n54 ( )	CELL n55 ( )	CELL n56 ( )	CELL n57 ( )	CELL n58 ( )	CELL n59
E8 (ROW 6)	CELL n61 ( )	CELL n62 ( )	CELL n63 ( )	CELL n64 ( )	CELL n65 ( )	CELL n66 ( )	CELL n67 ( )	CELL n68 ( )	CELL n69
E9 (ROW 7)	CELL n71 ( )	CELL n72 ( )	CELL n73 ( )	CELL n74 ( )	CELL n75 ( )	CELL n76 ( )	CELL n77 ( )	CELL n78 ( )	CELL n79

Figure 21. SCAMC Worksheet (Page 1)

inventory of 147,911 (i.e., "147911(1)(1980)"), consider the impact of stating the following:

> STATEMENT 1: 76,747 of the E1-E3s were not promoted to E4 during 1980; 42,302 of the E1-E3s were promoted to E4 during 1980; and 28,410 of the E1-E3s were discharged from the Navy during 1980.

> STATEMENT 2: 51.9 percent of the E1-E3s were not promoted to E4 during 1980; 28.4 percent of the E1-E3s were promoted to E4 during 1980; and 19.2 percent of the E1-E3s were discharged from the Navy during 1980.

Clearly, the three substatements included in Statement 2 have more practical significance, and are more descriptive of the E1-E3 paygrade during the year between the start of 1980 and the start of 1981. It is for this reason that SCAMC will accept entry of raw data (whole numbers), and later automatically convert it into proportions. More specifically, internal flows, attrition, and recruitment are the data that are converted into proportions. When converted into proportions, data titles are changed to reflect the difference between raw and proportion data, however, their definition basically retains its meaning as defined earlier in the paper. A comparative illustration of the titles is shown in Figure 22.

RAW DATA The number of people who...	PROPORTION DATA The percent of people who...
internal flow n(ij)(T-1)	transition probabilities p(ij)(T-1)
attrition n(i,k+1)(T-1)	attrition rate w(i)
recruitment n(Øi)(t)	recruitment rate r(i)
internal flow matrix N = (n(ij))	transition matrix p = (p(ij))

Figure 22. Comparison of Raw and Proportion Data

I. SCAMC'S PERSONNEL FLOW EQUATIONS

The relationships expressed in the YEARLY GRADE TABLE for beginning and ending inventories, and thus those incorporated in SCAMC, may be algebraically expressed as follows:

RAW NUMBER EQUATIONS

Beginning inventories:

$$n(i)(t-1) = \Sigma\, n(ij)(T-1) + n(i,k+1)(T-1)$$

Ending inventories:

$$n(i)(t) = \Sigma\, n(ij)(T-1) + n(\emptyset i)(t)$$

Where: $i,j = 1,2,3,4,5,6,7$
$k = 7$

PROPORTIONS

Beginning inventories:

$$n(i)(t-1) = \Sigma\, p(ij)(T-1) + w(i)(T-1)$$

Ending inventories:

$$n(i)(t) = \Sigma\, p(ij)(T-1) + r(i)(t)$$

Where: $i,j = 1,2,3,4,5,6,7$
$p(ij) = n(ij)(T-1)/n(i)(t-1)$ = transition probability
$w(i) = n(i,k+1)(T-1)/n(i)(t)$ = attrition rate
$R(t) = \Sigma\, n(\emptyset i)(t)$ = total recruitment
$r(i) = n(\emptyset i)(t)/R(t)$ = recruitment proportion

J. SCAMC DATA ENTRY

As discussed earlier, although SCAMC permits entry of proportions, it is designed to accept entry of raw data. This allows the analyst to enter data obtained via "Green Books", Chief of Naval Education and Training (CNET) records, Defense Manpower Data Center (DMDC) files, or other similar sources, directly into the calculator. The burden of manually converting the raw data into proportions by hand is not required.

V. SCAMC EXAMPLE

> An ounce of application is worth a ton of abstraction.
>
> --Booker's law

A. BACKGROUND

This section provides an example of a manpower planning problem that may be analyzed through the application of SCAMC. The interest here is <u>not</u> to offer solutions or a particular recommendation. Rather, the example is used to demonstrate SCAMC's ability to independently untangle complex manpower questions. Of course, once an initial direction to pursue analytical investigation is understood, users may then proceed to more sophisticated levels of analysis.

Two differing <u>HYPOTHETICAL</u> points of view concerning a manpower planning problem are presented below for analytical consideration. Both points of view were formulated during January 1981, in response to questions regarding the number of personnel to recruit into the Navy at the E1 through E3 paygrades between 1982 and 1987.

1. Hypothetical NPRDC Point of View

The Navy Personnel Research and Development Center (NPRDC) in San Diego has stated that, although the Navy has

been reasonably successful in meeting first term accession objectives, the problem of retaining qualified personnel beyond their initial enlistment continues to plague manning requirements. As a result, they feel that unless recruitment quotas are raised by a significant amount to a level that facilitates effective readiness, the Navy's manpower posture between 1982 and 1987 will be poor. This situation, it is said, will cause many Navy systems to be manned and maintained by personnel with marginal skills and experience that may not sustain optimum system performance. It is paradoxical, the Center thus finds, that current Naval manpower strategy is formulated on the development of an operational fleet consisting of some 600-plus ships. Likewise, they anticipate that the current decline of the Navy's primary source of manpower (i.e., young men between 17 and 21 years of age) will continue well into the 1990s. The potential for moderate economic growth (i.e., 8.9 percent to 6.5 percent declining unemployment) during the next few years further strengthens the Center's opinion.

2. Hypothetical MMTF Point of View

A recent report of the Military Manpower Task Force (MMTF) disagrees with NPRDC's assessment. The Task Force findings indicate that the supply of qualified personnel who stay past their initial enlistment will rise, and proper

force manning is an obtainable objective given current pay-grade recruitment quotas and legally mandated promotion and attrition levels. The Task Force findings are supported by calculations that suggest a limited demand for manpower growth in spite of the 600-ship goal. The Task Force agrees with NPRDC regarding a decrease in the pool of eligible accessions; however, because of limited demand for manpower growth, such declines are acceptable. Their opinion is predicated on the belief that a divergence between manpower demand and supply is minimized by favorable projections of retention. That these projections, if accurate, will help to hold down the number of accessions required for necessary manning. Thus, it is anticipated that only "relatively modest shortfalls" will occur and can be overcome by appropriate combinations of enlistment bonuses and skill shortage pay for first-termers. The Task Force therefore recommends that 1981-based recruitment quotas, paygrade promotion rates, and attrition rates remain unchanged through 1987.

B. USING SCAMC: NPRDC VS. MMTF

The reader is asked to utilize SCAMC and the data presented in Tables I through IV to determine which of the assessments outlined above should be supported. Because the results of the analysis may become a formal part of the

TABLE I

NAVY ENLISTMENT SUPPLY PROJECTIONS
(1982 through 1987)

Moderate economic growth
(8.9 to 6.6 percent declining unemployment)
(Data are numbers of NPS male Navy enlistees)

YEAR	TOTAL
1982	70,698
1983	64,667
1984	59,667
1985	57,049
1986	54,599
1987	53,764

Source: Reference 5

TABLE II

TOTAL NAVY ENLISTED BILLET REQUIREMENTS BY PAYGRADE VS. FISCAL YEAR

PAYGRADE	YEARS					
	1982	1983	1984	1985	1986	1987
E1-E3	171,567	175,126	176,935	179,282	182,662	186,887
E4	107,946	108,896	110,002	112,158	114,358	116,704
E5	102,814	104,251	105,373	109,998	109,295	111,356
E6	80,520	81,726	82,433	83,976	85,537	87,193
E7	34,117	34,607	34,911	35,554	36,245	36,787
E8	10,017	10,163	10,226	10,403	10,611	10,797
E9	4,251	4,309	4,343	4,484	4,484	4,558

Source: Reference 5

TABLE III

TOTAL NAVY ENLISTED BILLET AUTHORIZATIONS
AND REQUIREMENTS BY FISCAL YEAR

YEAR	AUTHORIZATIONS	TOTAL REQUIREMENTS (Table II)
1982	480,149	511,241
1983	504,874	519,078
1984	516,285	524,223
1985	528,381	533,330
1986	534,081	543,192
1987	540,561	554,272

Source: ENLISTED PROGRAMMED AUTHORIZATIONS and Reference 5

TABLE IV

NAVY ACTIVE DUTY ENLISTED PERSONNEL BY
TYPE OF FLOW AND PAYGRADE FLOW DATA
(Numbers)

	PAYGRADE						
TYPE OF FLOW	E1-E3	E4	E5	E6	E7	E8	E9
Not Advanced	76,747	35,738	38,144	32,446	14,768	4,238	1,907
Advanced One Paygrade	42,302	23,569	10,101	4,976	1,533	565	none
Advanced Two Paygrades	452	none	none	none	none	none	none
Demoted One Paygrade	none	20,202	628	163	none	none	none
Demoted Two Paygrades	none	none	122	none	none	none	none
Paygrade Attrition	28,410	22,748	12,744	4,817	2,544	916	475

Source: DMDC (FY 1981 data) and Reference 5

strategic planning policy of the Naval Military Personnel Command (OP-12) and Office of the Chief of Naval Operations, the reader should also be able to support and demonstrate the logic used to develop his or her recommendation.

C. DATA

1. Enlisted Personnel Supply Projections

Projections of the number of qualified non-prior service (NPS) enlisted personnel were provided by a Rand Corporation model [Ref. 5]. The model predicts the expected enlistments of NPS male high school diploma graduates for each of mental categories I and II, IIIA and IIIB, as a function of the Military/civilian pay ratio, production recruits, and the unemployment rate for 16 to 19 year-old males. The available pool, consisting of NPS enlistment projections, is shown in Table I [Ref. 5]. In Table I, mental categories I, II, IIIA, and IIIB are combined; therefore, only totals are shown. This is sufficient for the example.

Both NPRDC and MMTF based their projections on moderate economic growth. Because of a distrust of various projection factors incorporated in the Rand model, NPRDC selected to use one recursive enlistment supply projection. (Specifically, the Center selected use of the average of yearly enlistment projections for the years of 1982 through

1987 (inclusive).) This average equated to 60,077 accessions per year. The MMTF, however, formulated their point of view by assuming the Navy would indeed recruit 100 percent of the actual yearly projection for 1981; this amounted to: 70,698 in 1982; 64,667 in 1983; etc.; 53,764 in 1987. For purposes of simplification, readers are to assume the data presented in Tables I through IV were the only information available to both NPRDC and the MMTF during their various states of research.

2. Navy Manpower Requirements Determination

An unpublished method for aggregate manpower requirements determination, suggested by the Manpower Personnel and Training Analysis curriculum at the Naval Postgraduate School, was selected as the basis for future manpower requirement projections. This method reflects the total enlisted billet requirements, and includes the sum of ship, aviation and support requirements. Total enlisted billets requirements are shown in Table II [Ref. 5].

As desirable as full mission capability may be, the manpower requirements to achieve it are in excess of the numbers of bunks and facilities available to support them. Consequently, congressional manpower authorizations reflect bunk constrained figures. The bunk constrained figures, as reported in the ENLISTED PROGRAMMED AUTHORIZATIONS, are the figures used as annual required end strengths in the

accessions determination process. The ENLISTED PROGRAMMED AUTHORIZATIONS provided in Table III [Ref. 5] cover the period from FY 1982 to FY 1987.

3. Personnel Flow Data

A personnel flow matrix, it is noted, describes the movement of personnel in the system over a specific period of time as a result of attrition, retention, and promotion conditions for that period. The information shown in Table IV may be formatted as a matrix. It is based on 1981 data provided by the Defense Manpower Data Center (DMDC) and shows behavior by personnel in the system during that year only. (An assumption is made that the matrix would reflect system behavior in subsequent years through 1987.)

The personnel flow matrix used by NPRDC and the MMTF is based on the data presented in Table IV.

4. Abbreviated Program Execution Procedure

The sequence of steps shown below are abbreviated to demonstrate use of the calculator software in analyzing NPRDC's point of view. The steps follow the sequence of steps on the SCAMC user instructions. (Readers may wish to place SCAMC user instruction sheets presented in Appendix B alongside the following abbreviated sequential steps.)

STEPS GENERAL PROCEDURE

1 to 1.A Enter (NPRDC) requirement data for all paygrades into designated worksheet cells (i.e., n(Ø1) through n(Ø7).

GRADE	E1-E3 Column 1	E4 Column 2	E5 Column 3	E6 Column 4	E7 Column 5	E8 Column 6	E9 Column 7		
RECRUIT DATA (ROW 0)	CELL n01 60,077 ( )	CELL n02 0 (0)	CELL n03 0 (0)	CELL n04 0 (0)	CELL n05 0 (0)	CELL n06 0 (0)	CELL n07 0 (0)	ATTRITION Column 8	BEG. INV. Column 9
E1-E3 (ROW 1)	CELL n11 ( )	CELL n12 ( )	CELL n13 ( )	CELL n14 ( )	CELL n15 ( )	CELL n16 ( )	CELL n17 ( )	CELL n18 ( )	CELL n19
E4 (ROW 2)	CELL n21 ( )	CELL n22 ( )	CELL n23 ( )	CELL n24 ( )	CELL n25 ( )	CELL n26 ( )	CELL N27 ( )	CELL n28 ( )	CELL n29
E5 (ROW 3)	CELL n31 ( )	CELL n32 ( )	CELL n33 ( )	CELL n34 ( )	CELL n35 ( )	CELL n36 ( )	CELL n37 ( )	CELL n38 ( )	CELL n39
E6 (ROW 4)	CELL n41 ( )	CELL n42 ( )	CELL n43 ( )	CELL n44 ( )	CELL n45 ( )	CELL n46 ( )	CELL n47 ( )	CELL n48 ( )	CELL n49
E7 (ROW 5)	CELL n51 ( )	CELL n52 ( )	CELL n53 ( )	CELL n54 ( )	CELL n55 ( )	CELL n56 ( )	CELL n57 ( )	CELL n58 ( )	CELL n59
E8 (ROW 6)	CELL n61 ( )	CELL n62 ( )	CELL n63 ( )	CELL n64 ( )	CELL n65 ( )	CELL n66 ( )	CELL n67 ( )	CELL n68 ( )	CELL n69
E9 (ROW 7)	CELL n71 ( )	CELL n72 ( )	CELL n73 ( )	CELL n74 ( )	CELL n75 ( )	CELL n76 ( )	CELL n77 ( )	CELL n78 ( )	CELL n79

STEPS	GENERAL PROCEDURE
1.B to 1.B.11	Enter DMDC personnel flow and attrition data into appropriate worksheet cells. (See Table IV.)

GRADE	E1-E3 Column 1	E4 Column 2	E5 Column 3	E6 Column 4	E7 Column 5	E8 Column 6	E9 Column 7		
RECRUIT DATA (ROW 0)	CELL n01 60,077 (.519)	CELL n02 0 (0)	CELL n03 0 (0)	CELL n04 0 (0)	CELL n05 0 (0)	CELL n06 0 (0)	CELL n07 0 (0)	ATTRITION Column 8	BEG. INV. Column 9
E1-E3 (ROW 1)	CELL n11 76,747 ( )	CELL n12 42,302 ( )	CELL n13 452 ( )	CELL n14 0 ( )	CELL n15 0 ( )	CELL n16 0 ( )	CELL n17 0 ( )	CELL n18 28,410 ( )	CELL n19
E4 (ROW 2)	CELL n21 20,202 ( )	CELL n22 35,738 ( )	CELL n23 23,569 ( )	CELL n24 0 ( )	CELL n25 0 ( )	CELL n26 0 ( )	CELL N27 0 ( )	CELL n28 22,748 ( )	CELL n29
E5 (ROW 3)	CELL n31 0 ( )	CELL n32 628 ( )	CELL n33 38,144 ( )	CELL n34 10,101 ( )	CELL n35 0 ( )	CELL n36 0 ( )	CELL n37 0 ( )	CELL n38 12,744 ( )	CELL n39
E6 (ROW 4)	CELL n41 0 ( )	CELL n42 0 ( )	CELL n43 163 ( )	CELL n44 32,446 ( )	CELL n45 4,976 ( )	CELL n46 0 ( )	CELL n47 0 ( )	CELL n48 4,817 ( )	CELL n49
E7 (ROW 5)	CELL n51 0 ( )	CELL n52 0 ( )	CELL n53 0 ( )	CELL n54 0 ( )	CELL n55 14,768 ( )	CELL n56 1,533 ( )	CELL n57 0 ( )	CELL n58 2,544 ( )	CELL n59
E8 (ROW 6)	CELL n61 0 ( )	CELL n62 0 ( )	CELL n63 0 ( )	CELL n64 0 ( )	CELL n65 0 ( )	CELL n66 4,238 ( )	CELL n67 565 ( )	CELL n68 916 ( )	CELL n69
E9 (ROW 7)	CELL n71 0 ( )	CELL n72 0 ( )	CELL n73 0 ( )	CELL n74 0 ( )	CELL n75 0 ( )	CELL n76 0 ( )	CELL n77 1,907 ( )	CELL n78 475 ( )	CELL n79

STEPS GENERAL PROCEDURE

1.C to 1.C.5 Enter the beginning inventory for each paygrade into respective worksheet cell. A paygrade beginning inventory may be calculated by adding its sum of personnel flows to attrition. (See Section IV.G for equation.)

GRADE	E1-E3 Column 1	E4 Column 2	E5 Column 3	E6 Column 4	E7 Column 5	E8 Column 6	E9 Column 7		
RECRUIT DATA (ROW 0)	CELL n01 60,077 (.519)	CELL n02 0 (0)	CELL n03 0 (0)	CELL n04 0 (0)	CELL n05 0 (0)	CELL n06 0 (0)	CELL n07 0 (0)	ATTRITION Column 8	BEG. INV. Column 9
E1-E3 (ROW 1)	CELL n11 76,747 ( )	CELL n12 42,302 ( )	CELL n13 452 ( )	CELL n14 0 ( )	CELL n15 0 ( )	CELL n16 0 ( )	CELL n17 0 ( )	CELL n18 28,410 ( )	CELL n19 147,911
E4 (ROW 2)	CELL n21 20,202 ( )	CELL n22 35,738 ( )	CELL n23 23,569 ( )	CELL n24 0 ( )	CELL n25 0 ( )	CELL n26 0 ( )	CELL N27 0 ( )	CELL n28 22,748 ( )	CELL n29 102,257
E5 (ROW 3)	CELL n31 122 ( )	CELL n32 628 ( )	CELL n33 38,144 ( )	CELL n34 10,101 ( )	CELL n35 0 ( )	CELL n36 0 ( )	CELL n37 0 ( )	CELL n38 12,744 ( )	CELL n39 61,739
E6 (ROW 4)	CELL n41 0 ( )	CELL n42 0 ( )	CELL n43 163 ( )	CELL n44 32,446 ( )	CELL n45 4,976 ( )	CELL n46 0 ( )	CELL n47 0 ( )	CELL n48 4,817 ( )	CELL n49 42,402
E7 (ROW 5)	CELL n51 0 ( )	CELL n52 0 ( )	CELL n53 0 ( )	CELL n54 0 ( )	CELL n55 14,768 ( )	CELL n56 1,533 ( )	CELL n57 0 ( )	CELL n58 2,544 ( )	CELL n59 18,845
E8 (ROW 6)	CELL n61 0 ( )	CELL n62 0 ( )	CELL n63 0 ( )	CELL n64 0 ( )	CELL n65 0 ( )	CELL n66 4,238 ( )	CELL n67 565 ( )	CELL n68 916 ( )	CELL n69 5,719
E9 (ROW 7)	CELL n71 0 ( )	CELL n72 0 ( )	CELL n73 0 ( )	CELL n74 0 ( )	CELL n75 0 ( )	CELL n76 0 ( )	CELL n77 1,907 ( )	CELL n78 475 ( )	CELL n79 2,382

<u>STEP</u> <u>GENERAL PROCEDURE</u>

1.D Enter recruitment beginning inventory for each paygrade into its respective cell on Page 2 of the worksheet (i.e., for the zero or initial year).

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Date: 29 JAN 81

Graph Attached Y/N

ANNUAL END STRENGTH DATA:

RECRUITMENT DATA		E1-E3 60,077 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:	
CAT.	GRADE	YEAR: 81		YEAR:		YEAR:		YEAR:		YEAR:	
1	E1-E3	0-1	147,911	1-1		2-1		3-1		4-1	
2	E4	0-2	102,257	1-2		2-2		3-2		4-2	
3	E5	0-3	61,739	1-3		2-3		3-3		4-3	
4	E6	0-4	42,402	1-4		2-4		3-4		4-4	
5	E7	0-5	18,845	1-5		2-5		3-5		4-5	
6	E8	0-6	5,719	1-6		2-6		3-6		4-6	
7	E9	0-7	2,382	1-7		2-7		3-7		4-7	

		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:	
CAT.	GRADE	YEAR:		YEAR:		YEAR:		YEAR:		YEAR:	
1	E1-E3	5-1		6-1		7-1		8-1		9-1	
2	E4	5-2		6-2		7-2		8-2		9-2	
3	E5	5-3		6-3		7-3		8-3		9-3	
4	E6	5-4		6-4		7-4		8-4		9-4	
5	E7	5-5		6-5		7-5		8-5		9-5	
6	E8	5-6		6-6		7-6		8-6		9-6	
7	E9	5-7		6-7		7-7		8-7		9-7	

NOTES:

(1) ______________________________

(2) ______________________________

(3) ______________________________

(4) ______________________________

STEPS	GENERAL PROCEDURE
2 to 6.G.9	Repartition calculator, reading magnetic cards 1 and 2, and enter data from the calculator as outlined by the user instructions. Electronically record data that was entered onto magnetic cards 3 and 4.

STEPS	GENERAL PROCEDURE
7 to 12.C	Read magnetic cards 5 and 6, transform data from raw numbers to probabilities, then record the transition data onto magnetic cards 7 and 8 as outlined by the user instructions.

STEPS	GENERAL PROCEDURE
13 to 13.B.7	Recall transformed data from calculator memory registers and manually write the information in the area within parentheses beneath the raw data presently written in the upper half of the respective cells.

GRADE	E1-E3 Column 1	E4 Column 2	E5 Column 3	E6 Column 4	E7 Column 5	E8 Column 6	E9 Column 7	ATTRITION Column 8	BEG. INV. Column 9
RECRUIT DATA (ROW 0)	CELL n01 60,077 (.519)	CELL n02 0 (0)	CELL n03 0 (0)	CELL n04 0 (0)	CELL n05 0 (0)	CELL n06 0 (0)	CELL n07 0 (0)		
E1-E3 (ROW 1)	CELL n11 76,747 (.519)	CELL n12 42,302 (.286)	CELL n13 452 (.003)	CELL n14 0 (0)	CELL n15 0 (0)	CELL n16 0 (0)	CELL n17 0 (0)	CELL n18 28,410 (.192)	CELL n19 147,911
E4 (ROW 2)	CELL n21 20,202 (.026)	CELL n22 35,738 (.424)	CELL n23 23,569 (.280)	CELL n24 0 (0)	CELL n25 0 (0)	CELL n26 0 (0)	CELL N27 0 (0)	CELL n28 22,748 (.270)	CELL n29 102,257
E5 (ROW 3)	CELL n31 122 (.002)	CELL n32 628 (.010)	CELL n33 38,144 (.618)	CELL n34 10,101 (.164)	CELL n35 0 (0)	CELL n36 0 (0)	CELL n37 0 (0)	CELL n38 12,744 (.206)	CELL n39 61,739
E6 (ROW 4)	CELL n41 0 (0)	CELL n42 0 (0)	CELL n43 163 (.004)	CELL n44 32,446 (.765)	CELL n45 4,976 (.118)	CELL n46 0 (0)	CELL n47 0 (0)	CELL n48 4,817 (.114)	CELL n49 42,402
E7 (ROW 5)	CELL n51 0 (0)	CELL n52 0 (0)	CELL n53 0 (0)	CELL n54 0 (0)	CELL n55 14,768 (.783)	CELL n56 1,533 (.081)	CELL n57 0 (0)	CELL n58 2,544 (.135)	CELL n59 18,845
E8 (ROW 6)	CELL n61 0 (0)	CELL n62 0 (0)	CELL n63 0 (0)	CELL n64 0 (0)	CELL n65 0 (0)	CELL n66 4,238 (.741)	CELL n67 565 (.099)	CELL n68 916 (.160)	CELL n69 5,719
E9 (ROW 7)	CELL n71 0 (0)	CELL n72 0 (0)	CELL n73 0 (0)	CELL n74 0 (0)	CELL n75 0 (0)	CELL n76 0 (0)	CELL n77 1,907 (.301)	CELL n78 475 (.199)	CELL n79 2,382

STEPS	GENERAL PROCEDURE
14 to 14.G	Reenter the original or desired recruitment data into the respective calculator memory registers.

STEPS	GENERAL PROCEDURE
15 to 2Ø	Read magnetic card 9 and commence program execution to calculate yearly end strengths for the set of assumptions defined by the worksheet. Manually write the results of each yearly calculation into the respective cells on Page 2 of the worksheet.

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Date: 29 JAN 81

Graph Attached Y/N

ANNUAL END STRENGTH DATA:

RECRUITMENT DATA		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:	
CAT.	GRADE	YEAR: 81		YEAR: 82		YEAR:		YEAR:		YEAR:	
1	E1-E3	0-1	147,911	1-1	139,178	2-1		3-1		4-1	
2	E4	0-2	102,257	1-2	78,670	2-2		3-2		4-2	
3	E5	0-3	61,739	1-3	62,328	2-3		3-3		4-3	
4	E6	0-4	42,402	1-4	42,547	2-4		3-4		4-4	
5	E7	0-5	18,845	1-5	19,744	2-5		3-5		4-5	
6	E8	0-6	5,917	1-6	5,791	2-6		3-6		4-6	
7	E9	0-7	2,383	1-7	2,472	2-7		3-7		4-7	

		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:	
CAT.	GRADE	YEAR:		YEAR:		YEAR:		YEAR:		YEAR:	
1	E1-E3	5-1		6-1		7-1		8-1		9-1	
2	E4	5-2		6-2		7-2		8-2		9-2	
3	E5	5-3		6-3		7-3		8-3		9-3	
4	E6	5-4		6-4		7-4		8-4		9-4	
5	E7	5-5		6-5		7-5		8-5		9-5	
6	E8	5-6		6-6		7-6		8-6		9-6	
7	E9	5-7		6-7		7-7		8-7		9-7	

NOTES:

(1) ______________________________

(2) ______________________________

(3) ______________________________

(4) ______________________________

STEPS	GENERAL PROCEDURE
Various	Repeat steps 14 through 20 for the number of years for which end strength projections are desired. Record resulting information into designated cells on Page 2 of the worksheet. This process should be repeated to reflect the alternative (MMTF) set of assumptions as shown on the following page.

Page 1 of 1

Date: 29 JAN 81

Graph Attached Y/N

ANNUAL END STRENGTH DATA:

RECRUITMENT DATA		E1-E3 OTHER:		E1-E3 60,077 OTHER:		E1-E3 60,077 OTHER:		E1-E3 60,077 OTHER:		E1-E3 60,077 OTHER:	
CAT.	GRADE	YEAR: 81		YEAR: 82		YEAR: 83		YEAR: 84		YEAR: 85	
1	E1-E3	0-1	147,911	1-1	139,148	2-1	134,456	3-1	131,892	4-1	130,468
2	E4	0-2	102,257	1-2	78,670	2-2	73,800	3-2	70,382	4-2	68,178
3	E5	0-3	61,739	1-3	62,328	2-3	61,103	3-3	58,970	4-3	56,688
4	E6	0-4	42,402	1-4	42,547	2-4	42,754	3-4	42,713	4-4	42,332
5	E7	0-5	18,845	1-5	19,744	2-5	20,449	3-5	21,025	4-5	21,472
6	E8	0-6	5,719	1-6	5,791	2-6	5,917	3-6	6,068	4-6	6,227
7	E9	0-7	2,382	1-7	2,472	2-7	4,951	3-7	4,548	4-7	9,112

		E1-E3 60,077 OTHER:		E1-E3 60,077 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:	
CAT.	GRADE	YEAR: 86		YEAR: 87		YEAR:		YEAR:		YEAR:	
1	E1-E3	5-1	129,667	6-1	129,212	7-1		8-1		9-1	
2	E4	5-2	66,812	6-2	65,983	7-2		8-2		9-2	
3	E5	5-3	54,656	6-3	53,014	7-3		8-3		9-3	
4	E6	5-4	41,667	6-4	40,826	7-4		8-4		9-4	
5	E7	5-5	21,776	6-5	21,937	7-5		8-5		9-5	
6	E8	5-6	6,382	6-6	6,522	7-6		8-6		9-6	
7	E9	5-7	13,691	6-7	18,285	7-7		8-7		9-7	

NOTES:

(1) ______________________________

(2) ______________________________

(3) ______________________________

(4) ______________________________

Page 1 of 1

Date: 29 JAN 81

Graph Attached Y/N

ANNUAL END STRENGTH DATA:

RECRUITMENT DATA		E1-E3 OTHER:		E1-E3 70,698 OTHER:		E1-E3 64,667 OTHER:		E1-E3 59,667 OTHER:		E1-E3 57,049 OTHER:	
CAT.	GRADE	YEAR: 81		YEAR: 82		YEAR: 83		YEAR: 84		YEAR: 85	
1	E1-E3	0-1	147,911	1-1	149,769	2-1	144,557	3-1	136,803	4-1	130,099
2	E4	0-2	102,257	1-2	78,670	2-2	76,838	3-2	74,560	4-2	71,363
3	E5	0-3	61,739	1-3	62,328	2-3	61,135	3-3	59,871	4-3	58,428
4	E6	0-4	42,402	1-4	42,547	2-4	42,754	3-4	42,718	4-4	42,483
5	E7	0-5	18,845	1-5	19,744	2-5	20,449	3-5	21,025	4-5	21,472
6	E8	0-6	5,917	1-6	5,791	2-6	5,917	3-6	6,068	4-6	6,227
7	E9	0-7	2,382	1-7	2,472	2-7	4,951	3-7	4,548	4-7	9,112

		E1-E3 54,599 OTHER:		E1-E3 53,764 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:	
CAT.	GRADE	YEAR: 86		YEAR: 87		YEAR:		YEAR:		YEAR:	
1	E1-E3	5-1	124,084	6-1	83,985	7-1		8-1		9-1	
2	E4	5-2	68,075	6-2	45,070	7-2		8-2		9-2	
3	E5	5-3	56,622	6-3	54,354	7-3		8-3		9-3	
4	E6	5-4	42,067	6-4	41,454	7-4		8-4		9-4	
5	E7	5-5	21,795	6-5	21,998	7-5		8-5		9-5	
6	E8	5-6	6,382	6-6	6,524	7-6		8-6		9-6	
7	E9	5-7	13,691	6-7	18,285	7-7		8-7		9-7	

NOTES:

(1)

(2)

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(4)

The results shown above may be used to support a particular position. Readers are encouraged to compare these results to total Navy enlisted authorizations (Table III) and determine what assumptions might be changed (i.e., transition probabilities) to "drive" the end strengths toward a particular objective. In addition, readers are encouraged to practice the application of SCAMC under various sets of assumptions.

The interpretation of SCAMC's results are not within the scope of the presentation. Nonetheless, the following general considerations are presented to give readers an idea of how SCAMC's product may be looked upon. For example, readers may wish to consider the following questions:

(1) Are annual paygrade end strength trends "favorable"?

(2) To what extent do paygrade or total force end strengths differ from those that are authorized?

(3) What is the marginal cost (i.e., increase, decrease, or none) of each year's manning levels with respect to regular military compensation, special pay, reenlistment bonuses, etc.?

(4) With respect to increases in each paygrade's personnel inventories, do end strengths indicate a "bulge" or influx of personnel moving through the system? If so, what is the significance of such a bulge (i.e., will it lead to a "petty officer shortfall")?

(5) What effect would changing transition probabilities for E5s have on total force end strength?

(6) If the attrition rate for E1-E3 is increased by 15 percent, will there be an eventual shortage of E5s? If so, when will this occur, and when would it become critical?

(7) What impact would an annual multiplictive or incremental increase or decrease in non-prior service recruitment goals have on the system? Likewise, what would the impact of various lateral entry policies have on end strengths or the age of the force?

(8) What effect increases in paygrade inventory have on the student inventories of training commands?

As the foregoing discussion suggests, the analysis of results are much more powerful than SCAMC. However, this assumes users have established criterion measurements for various Military policies he or she is interested in analyzing. Interpretation of results will expand one's conceptual comprehension of policies. SCAMC helps readers to internalize the criterion by making available a means of supporting the development of analytical methodology for the investigation, and interpretation of results as one's experience or needs suggest.

The next chapter provides a brief summary of SCAMC along with a discussion of limitations, and potential applications.

VI. DISCUSSION

In character, in manner, in style,
in all things, the supreme excellence
is simplicity.

—H. W. Longfellow

A. SUMMARY

The purpose of the thesis is to enhance the student's or practioner's understanding of manpower systems by means of a calculator adaptation of the Markov chain model (i.e, SCAMC). SCAMC allows the kind of "hands on" practice necessary for the development or refinement of analytical skills important to manpower system management. For example, Chapter V demonstrates how SCAMC accommodates analysis of personnel end strength under differing assumptions, and encourages the development of alternative scenarios or applications. It is anticipated that this type of approach to analysis will enhance comprehension of fundamental modeling concepts, and reduce superficial problem-solving or uninformed system decisionmaking. This is possible because SCAMC provides a means of facilitating: (1) inexpensive, effective diagnosis of manpower problems; (2) evaluation of manpower policy alternatives; (3) formulation of workable manpower system solutions; and (4) projection of future enlisted paygrade end strengths.

B. CAUTIONS AND LIMITATIONS

SCAMC's treatment of Markov analysis is not complete without a brief discussion regarding software cautions and limitations. To ensure proper application of SCAMC, the reader should, as a minimum, recognize the following:

(1) The basic theory of Markov process was incorporated in SCAMC because of the simplifying premise of Markovian flows. However, the apparent simplicity of Markov theory is misleading; even the most "uncomplicated" manpower cases involve difficult problems of classification, aggregation, statistical estimation and inference, and interpretation of results [Ref. 2].

(2) It is evident from the above that SCAMC, like all statistical models, has some limitations in its application for manpower analysis. For example, SCAMC's simulations do not consider cost. Without costing various personnel flow options, the analysis is weakened. In addition, SCAMC's supply-push software requires that promotions and other internal system movements be estimated by applying historical transition rates to paygrades. This is accomplished without considering whether billet vacancies exist, or whether individuals are truly qualified for advancement. (Such considerations are better suited to renewal analysis (i.e., demand-pull) or other types of analysis [Ref. 6].)

(3) Since SCAMC is not designed to produce "the" answer to a particular manpower problem -- as opposed to a statistical model of potential outcomes based on certain conditions -- it leaves to the analyst the task of selecting the various possible alternatives to personnel flows that are consistent with military requirements [Ref. 6].

(4) SCAMC is a calculator adaptation of a model. It is not itself a model and, therefore, not designed for a specific application. In fact, by modifying the designation of categories (i.e., from enlisted paygrades to officer ranks, training schools, civilian managerial levels, or the like) SCAMC may be applied universally to forecast, predict, or control other manpower systems.

As readers become better acquainted with SCAMC's capabilities, they should also reach a better understanding of the entire manpower system with its many interrelated parts and dynamic environmental elements. Yet, one cannot expect to succeed as a manpower manager, analyst, or policymaker simply by studying the relevant literature, listening to lectures, or becoming familiar with modeling concepts or applications [Ref. 7]. Indeed, one must develop an appreciation of the conditions and circumstances surrounding manpower systems. He or she must be sensitive to the limitations of the system being investigated, and capable of conceptually diagnosing each potential situation. Likewise, military goals, objectives, strategies, policys, or control mechanisms must be understood and precede analysis, Through such an approach, one may use SCAMC effectively to help recognize problems, issues, or solutions inherent in manpower systems or personnel management control. Given individual analytical skills and the "hands on" capability of SCAMC, the "Gordian Knot" of manpower system analysis may begin to unravel.

APPENDIX A

SCAMC WORKSHEET

GRADE	E1-E3 Column 1	E4 Column 2	E5 Column 3	E6 Column 4	E7 Column 5	E8 Column 6	E9 Column 7		
RECRUIT DATA (ROW 0)	CELL n01 ( )	CELL n02 ( )	CELL n03 ( )	CELL n04 ( )	CELL n05 ( )	CELL n06 ( )	CELL n07 ( )	ATTRITION Column 8	BEG. INV. Column 9
E1-E3 (ROW 1)	CELL n11 ( )	CELL n12 ( )	CELL n13 ( )	CELL n14 ( )	CELL n15 ( )	CELL n16 ( )	CELL n17 ( )	CELL n18 ( )	CELL n19
E4 (ROW 2)	CELL n21 ( )	CELL n22 ( )	CELL n23 ( )	CELL n24 ( )	CELL n25 ( )	CELL n26 ( )	CELL N27 ( )	CELL n28 ( )	CELL n29
E5 (ROW 3)	CELL n31 ( )	CELL n32 ( )	CELL n33 ( )	CELL n34 ( )	CELL n35 ( )	CELL n36 ( )	CELL n37 ( )	CELL n38 ( )	CELL n39
E6 (ROW 4)	CELL n41 ( )	CELL n42 ( )	CELL n43 ( )	CELL n44 ( )	CELL n45 ( )	CELL n46 ( )	CELL n47 ( )	CELL n48 ( )	CELL n49
E7 (ROW 5)	CELL n51 ( )	CELL n52 ( )	CELL n53 ( )	CELL n54 ( )	CELL n55 ( )	CELL n56 ( )	CELL n57 ( )	CELL n58 ( )	CELL n59
E8 (ROW 6)	CELL n61 ( )	CELL n62 ( )	CELL n63 ( )	CELL n64 ( )	CELL n65 ( )	CELL n66 ( )	CELL n67 ( )	CELL n68 ( )	CELL n69
E9 (ROW 7)	CELL n71 ( )	CELL n72 ( )	CELL n73 ( )	CELL n74 ( )	CELL n75 ( )	CELL n75 ( )	CELL n77 ( )	CELL n78 ( )	CELL n79

Page 1

Page ___ of ___

Date: __________

Graph Attached Y/N

ANNUAL END STRENGTH DATA:

RECRUITMENT DATA		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:	
CAT.	GRADE	YEAR:		YEAR:		YEAR:		YEAR:		YEAR:	
1	E1-E3	0-1		1-1		2-1		3-1		4-1	
2	E4	0-2		1-2		2-2		3-2		4-2	
3	E5	0-3		1-3		2-3		3-3		4-3	
4	E6	0-4		1-4		2-4		3-4		4-4	
5	E7	0-5		1-5		2-5		3-5		4-5	
6	E8	0-6		1-6		2-6		3-6		4-6	
7	E9	0-7		1-7		2-7		3-7		4-7	

		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:		E1-E3 OTHER:	
CAT.	GRADE	YEAR:		YEAR:		YEAR:		YEAR:		YEAR:	
1	E1-E3	5-1		6-1		7-1		8-1		9-1	
2	E4	5-2		6-2		7-2		8-2		9-2	
3	E5	5-3		6-3		7-3		8-3		9-3	
4	E6	5-4		6-4		7-4		8-4		9-4	
5	E7	5-5		6-5		7-5		8-5		9-5	
6	E8	5-6		6-6		7-6		8-6		9-6	
7	E9	5-7		6-7		7-7		8-7		9-7	

NOTES:

(1) ____

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(2) ____

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(3) ____

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(4) ____

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Page 2

APPENDIX B

SCAMC USER INSTRUCTIONS

CARD TITLE: N.A. CARD NO: N.A. CARD SIDE: N.A.

STEP DESCRIPTION: Enter known information into user worksheet.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
1	N.A.*	Manually enter data into designated cells on user worksheet.	N.A.	N.A.	N.A.
1.A	All	Enter recruitment data for E1-E3, E4, E5,..., E9 into respective cells n01, n02, n03,..., n07.	N.A.	N.A.	N.A.
1.B		Enter advancement and attrition data into designated worksheet cells. For example:	N.A.	N.A.	N.A.
1.B.1	E1-E3	Enter the number of E1-E3 personnel not advanced into cell n11.	N.A.	N.A.	N.A.
1.B.2		Enter the number of E1-E3 personnel advanced to E4 into cell n12.	N.A.	N.A.	N.A.
1.B.3		Enter the number of E1-E3 personnel advanced to E5 into cell n13.	N.A.	N.A.	N.A.
1.B.4		ETC.	N.A.	N.A.	N.A.
1.B.5		Enter the number of E1-E3 personnel who attrited from the paygrade into cell n18.	N.A.	N.A.	N.A.
1.B.6	E4	Enter the number of E4 personnel demoted to E1-E3 into cell n21.	N.A.	N.A.	N.A.

* Not Applicable.

CARD TITLE: N.A. CARD NO: N.A. CARD SIDE: N.A.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
1.B.7		Enter the number of E4 personnel not advanced into cell n22.	N.A.	N.A.	N.A.
1.B.8		Enter the number of E4 personnel advanced to E5 into cell n23.	N.A.	N.A.	N.A.
1.B.9		ETC.	N.A.	N.A.	N.A.
1.B.10		Enter the number of E4 personnel who attrited from the paygrade into cell n28.	N.A.	N.A.	N.A.
1.B.11		Enter remaining advancement and attrition data into respective worksheet cells for paygrades E5 thru E9 as necessary.	N.A.	N.A.	N.A.
1.C		Enter beginning inventory (BI) for each paygrade into cells n19, n29,..., n79 as necessary*. For example:	N.A.	N.A.	N.A.
1.C.1	E1-E3	Enter E1-E3 BI into cell n19.	N.A.	N.A.	N.A.
1.C.2	E4	Enter E4 BI into cell n29.	N.A.	N.A.	N.A.
1.C.3	E5	Enter E5 BI into cell n39.	N.A.	N.A.	N.A.
1.C.4	ETC.	ETC.	N.A.	N.A.	N.A.
1.C.5	E9	Enter E9 BI into cell n79.	N.A.	N.A.	N.A.
1.D		Enter paygrade recruitment, year, and BI data into respective cells 0-1, 0-2, ..., 0-9 for beginning year.	N.A.	N.A.	N.A.

* If beginning inventory calculations are required, see the (beginning inventory) equation in Section IV.I.

CARD TITLE: Data Entry CARD NO. 1 & 2 CARD SIDE: 1,2,3,4

STEP DESCRIPTION: Transfer information from yearly grade table into calculator memory.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
2	N.A.	Repartition Calculator.	N.A.	9 2nd op 17	239.89
3.A	N.A.	Read Card 1, Side 1	N.A.	1 Feedcard	1
3.B	N.A.	Read Card 1, Side 2	N.A.	2 Feedcard	2
3.C	N.A.	Read Card 2, Side 3	N.A.	3 Feedcard	3
3.D	N.A.	Read Card 2, Side 4	N.A.	4 Feedcard	4
4	N.A.	Initialize calculator for data entry commencing from Row 0, cell n01.	N.A.	A	.01pl
5	N.A.	Enter recruitment data (Row 0) starting with cell n01.	N.A.	N.A.	N.A.
5.A	E1-E3	Enter number of personnel recruited into paygrade E1-E3, at time (t) from cell n01.	n01	R/S	2
5.B	E4	Continue above; enter data from cell n02.	n02	R/S	3
5.C	E5	Enter data from cell n03.	n03	R/S	4
5.D	E6	Enter data from cell n04	n04	R/S	5
5.E	E7	Enter data from cell n05.	n05	R/S	6
5.F	E8	Enter data from cell n06.	n06	R/S	7
5.G	E9	Enter data from cell n07.	n07	R/S	9.99 99pll*

* p = Short Pause.

CARD TITLE: Data Entry CARD NO: 1 & 2 CARD SIDE: 1,2,3,4

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
6	N.A.	Enter internal flow, attrition and beginning inventory for all paygrades from the designated cells.	N.A.	N.A.	N.A.
6.A	E1-E3	Initialize calculator for entry commencing from Row 1, Cell 1.	N.A.	2ndA'	11p1
6.A.1		Enter data from Cell n11.	n11	R/S	2
6.A.2		Enter data from Cell n12.	n12	R/S	3
6.A.3		Enter data from Cell n13.	n13	R/S	4
6.A.4		Enter data from Cell n14.	n14	R/S	5
6.A.5		Enter data from Cell n15	n15	R/S	6
6.A.6		Enter data from Cell n16.	n16	R/S	7
6.A.7		Enter data from Cell n17.	n17	R/S	8
6.A.8		Enter data from Cell n18.	n18	R/S	9
6.A.9		Enter data from Cell n19.	n19	R/S	9.99 99p21
6.B	E4	Initialize calculator for data entry commencing from Row 2, Cell 1.	N.A.	B	21p1
6.B.1		Enter data from Cell n21.	n21	R/S	2
6.B.2		Enter data from Cell n22.	n22	R/S	3
6.B.3		Enter data from Cell n23.	n23	R/S	4
6.B.4		Enter data from Cell n24.	n24	R/S	5
6.B.5		Enter data from Cell n25.	n25	R/S	6
6.B.6		Enter data from Cell n26.	n26	R/S	7
6.B.7		Enter data from Cell n27.	n27	R/S	8
6.B.8		Enter data from Cell n28.	n28	R/S	9
6.B.9		Enter data from Cell n29.	n29	R/S	9.99 99p31

CARD TITLE: Data Entry CARD NO: 1 & 2 CARD SIDE: 1,2,3,4

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
6.C	E5	Initialize calculator for data entry commencing from Row 3, Cell 1.	N.A.	2ndB'	31pl
6.C.1		Enter data from Cell n31.	n31	R/S	2
6.C.2		Enter data from Cell n32.	n32	R/S	3
6.C.3		Enter data from Cell n33.	n33	R/S	4
6.C.4		Enter data from Cell n34.	n34	R/S	5
6.C.5		Enter data from Cell n35.	n35	R/S	6
6.C.6		Enter data from Cell n36.	n36	R/S	7
6.C.7		Enter data from Cell n37.	n37	R/S	8
6.C.8		Enter data from Cell n38.	n38	R/S	9
6.C.9		Enter data from Cell n39.	n39	R/S	9.99 99p41
6.D	E6	Initialize calculator for data entry commencing from Row 4, Cell 1.	N.A.	C	41pl
6.D.1		Enter data from Cell n41.	n41	R/S	2
6.D.2		Enter data from Cell n42.	n42	R/S	3
6.D.3		Enter data from Cell n43.	n43	R/S	4
6.D.4		Enter data from Cell n44.	n44	R/S	5
6.D.5		Enter data from Cell n45.	n45	R/S	6
6.D.6		Enter data from Cell n46.	n46	R/S	7
6.D.7		Enter data from Cell n47.	n47	R/S	8
6.D.8		Enter data from Cell n48.	n48	R/S	9
6.D.9		Enter data from Cell n49.	n49	R/S	9.99 99p51

CARD TITLE: Data Entry CARD NO: 1 & 2 CARD SIDE: 1,2,3,4

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
6.E	E7	Initialize calculator for data entry commencing from Row 5, Cell 1.	N.A.	2ndC'	51pl
6.E.1		Enter data from Cell n51.	n51	R/S	2
6.E.2		Enter data from Cell n52.	n52	R/S	3
6.E.3		Enter data from Cell n53.	n53	R/S	4
6.E.4		Enter data from Cell n54.	n54	R/S	5
6.E.5		Enter data from Cell n55.	n55	R/S	6
6.E.6		Enter data from Cell n56.	n56	R/S	7
6.E.7		Enter data from Cell n57.	n57	R/S	8
6.E.8		Enter data from Cell n58.	n58	R/S	9
6.E.9		Enter data from Cell n59.	n59	R/S	9.99 99p61
6.F	E8	Initialize calculator for data entry commencing from Row 6, Cell 1.	N.A.	D	61pl
6.F.1		Enter data from Cell n61.	n61	R/S	2
6.F.2		Enter data from Cell n62.	n62	R/S	3
6.F.3		Enter data from Cell n63.	n63	R/S	4
6.F.4		Enter data from Cell n64.	n64	R/S	5
6.F.5		Enter data from Cell n65.	n65	R/S	6
6.F.6		Enter data from Cell n66.	n66	R/S	7
6.F.7		Enter data from Cell n67.	n67	R/S	8
6.F.8		Enter data from Cell n68.	n68	R/S	9
6.F.9		Enter data from Cell n69.	n69	R/S	9.99 99p71

CARD TITLE: Data Entry CARD NO: 1 & 2 CARD SIDE: 1,2,3,4

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
6.G	E9	Initialize calculator for data entry commencing from Row 7, Cell 1.	N.A.	2ndD'	71pl
6.G.1		Enter data from Cell n71.	n71	R/S	2
6.G.2		Enter data from Cell n72.	n72	R/S	3
6.G.3		Enter data from Cell n73.	n73	R/S	4
6.G.4		Enter data from Cell n74.	n74	R/S	5
6.G.5		Enter data from Cell n75.	n75	R/S	6
6.G.6		Enter data from Cell n76.	n76	R/S	7
6.G.7		Enter data from Cell n77.	n77	R/S	8
6.G.8		Enter data from Cell n78.	n78	R/S	9
6.G.9		Enter data from Cell n79.	n79	R/S	9.99 99p81

CARD TITLE: Transition Calculations CARD NO: 5 & 6 CARD SIDE: 1

STEP DESCRIPTION: Transform (RAW) internal flows, attrition, and recruitment into transition probabilities, wastage rates and recruitment proportions.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
7	N.A.	Read Card 5, Side 1.	N.A.	1 Feedcard	1
8	E1-E9	Transform recruitment information (by paygrade) into recruitment proportions.	N.A.	A	.01pp9.99 99p11
9	N.A.	Transform internal flows to transition probabilities for paygrade, E1-E6.	N.A.	N.A.	N.A.
9.A	E1-E3		N.A.	2ndA'	11p9.99 99p21
9.B	E4		N.A.	B	21p9.99 99p31
9.C	E5		N.A.	2ndB'	31p9.99 99p41
9.D	E6		N.A.	C	41p9.99 99p51
10	N.A.	Read Card 6, Side 1.	N.A.	N.A.	N.A.
11	N.A.	Transform internal flows to transition probabilities for paygrades, E7-E9.	N.A.	N.A.	N.A.
11.A	E7		N.A.	2ndC'	51p9.99 99p61
11.B	E8		N.A.	D	61p9.99 99p71
11.C	E9		N.A.	2ndD'	71p9.99 99p81

CARD TITLE: Record Transitions CARD NO: 7 & 8 CARD SIDE: 1,2,3,4

STEP DESCRIPTION: Record transformed data onto magnetic cards.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
12	N.A.	Write data onto Card 7, Side 1.	N.A. N.A.	1,2nd Write Feedcard	N.A. 1
12.A		Write data onto Card 7, Side 2.	N.A. N.A.	2,2nd Write Feedcard	N.A. 2
12.B		Write data onto Card 8, Side 3.	N.A. N.A.	3,2nd Write Feedcard	N.A. 3
12.C		Write data onto Card 8, Side 4.	N.A. N.A.	4,2nd Write Feedcard	N.A. 4

CARD TITLE: N.A. CARD NO: N.A. CARD SIDE: N.A.

STEP DESCRIPTION: Manually record transformed data (presently stored in calculator short-term memroy) beneath "raw" data currently shown in each cell on worksheet.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
13		Recall and Record paygrade recruitment proportions onto worksheet in designated cells (n01, n02,..., n07) in parenthesises beneath the "raw" data currently shown.	N.A.	N.A.	N.A.
13.A	E1-E3		N.A.	RCL81*	no %
13.A.1	E2		N.A.	RCL82	no %
13.A.2	E3		N.A.	RCL83	no %
13.A.3	E4		N.A.	RCL84	no %
13.A.4	E5		N.A.	RCL85	no %
13.A.5	E6		N.A.	RCL86	no %
13.A.6	E7		N.A.	RCL87	no %
13.A.7	E8		N.A.	RCL88	no %
13.A.8	E9		N.A.	RCL89	no %
13.B.1	E1-E3	Recall proportion data (as required) from designated cells for personnel flows and attrition, and write beneath "raw" data which is presently written in the upper-half of the worksheet.			
			N.A.	RCL11	n11 %
			N.A.	RCL12	n12 %
			N.A.	RCL13	n13 %
			N.A.	RCL14	n14 %
			N.A.	RCL15	n15 %
			N.A.	RCL16	n16 %
			N.A.	RCL17	n17 %
			N.A.	RCL18	n18 %

* RCL = Recall from calculator memory.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
13.B.2	E4		N.A.	RCL21	n21 %
			N.A.	RCL22	n22 %
			N.A.	RCL23	n23 %
			N.A.	RCL24	n24 %
			N.A.	RCL25	n25 %
			N.A.	RCL26	n26 %
			N.A.	RCL27	n27 %
			N.A.	RCL28	n28 %
13.B.3	E5		N.A.	RCL31	n31 %
			N.A.	RCL32	n32 %
			N.A.	RCL33	n33 %
			N.A.	RCL34	n34 %
			N.A.	RCL35	n35 %
			N.A.	RCL36	n36 %
			N.A.	RCL37	n37 %
			N.A.	RCL38	n38 %
13.B.4	E6		N.A.	RCL41	n41 %
			N.A.	RCL42	n42 %
			N.A.	RCL43	n43 %
			N.A.	RCL44	n44 %
			N.A.	RCL45	n45 %
			N.A.	RCL46	n46 %
			N.A.	RCL47	n47 %
			N.A.	RCL48	n48 %
13.B.5	E7		N.A.	RCL51	n51 %
			N.A.	RCL52	n52 %
			N.A.	RCL53	n53 %
			N.A.	RCL54	n54 %
			N.A.	RCL55	n55 %
			N.A.	RCL56	n56 %
			N.A.	RCL57	n57 %
			N.A.	RCL58	n58 %
13.B.6	E8		N.A.	RCL61	n61 %
			N.A.	RCL62	n62 %
			N.A.	RCL63	n63 %
			N.A.	RCL64	n64 %
			N.A.	RCL65	n65 %
			N.A.	RCL66	n66 %
			N.A.	RCL67	n67 %
			N.A.	RCL68	n68 %

STEP	GRADE	PROCEDURE	ENTRY	PRESS	DISPLAY
13.B.7	E9		N.A.	RCL71	n71 %
			N.A.	RCL72	n72 %
			N.A.	RCL73	n73 %
			N.A.	RCL74	n74 %
			N.A.	RCL75	n75 %
			N.A.	RCL76	n76 %
			N.A.	RCL77	n77 %
			N.A.	RCL78	n78 %

CARD TITLE: Yearly Ending Inventory CARD NO: 9 CARD SIDE: 1

STEP DESCRIPTION: Calculate the yearly ending inventory for the number of years required.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
14	N.A.	Store original or desired "raw" recruitment into each paygrade recruitment cell (n01, n02, etc..., n07). In place of recruitment proportion, that is, presently stored in respective memory registers.	N.A.	N.A.	N.A.
14.A	E1-E3	Store "raw" recruitment data into cell n01.	n01	STO 00*	n01
14.B	E4	Store "raw" recruitment data into cell n02.	n02	STO82	n02
14.C	E5	Store "raw" recruitment data into cell n03.	n03	STO83	n03
14.D	E6	Store "raw" recruitment data into cell n04.	n04	STO84	n04
14.E	E7	Store "raw" recruitment data into cell n05.	n05	STO85	n05
14.F	E8	Store "raw" recruitment data into cell n06.	n06	STO86	n06
14.G	E9	Store "raw" recruitment data into cell n07.	n07	STO87	n07
15	N.A.	Read Card 9, Side 1.	N.A.	1 Feedcard	1
16		Initialize calculator to calculate ending inventories.	N.A.	A	p10
17		Calculate yearly ending inventories for paygrades E1-E3 thru E9.	N.A.	R/S	10pp**
18		Sequentially display ending inventories commencing with category 1 (E1-E3), and proceeding thru category 7 (E9)			

* STO = Store in memory register.

** pp = Long pause.

STEP	GRADE	PROCEDURE	ENTER	PRESS	DISPLAY
18.A	E1-E3	Manually write the calculated ending inventory for year "n" into a E1-E3 cell for the respective year; e.g., for first year enter data into cell 1-1, for second year enter data into cell 2-1, etc., for nth year enter data into cell n-1.	N.A.	R/S	1p n-1
18.B	E4	Manually write the calculated ending inventory for year n; into a E4 cell for the respective year.	N.A.	R/S	2p n-2
18.C	E5	Manually write the calculated ending inventory data into respective E5 cell.	N.A.	R/S	3p n-1
18.D	E6	Manually write the calculated ending inventory data into respective E6 cell.	N.A.	R/S	4p n-4
18.E	E7	Manually write the calculated ending inventory data into respective E7 cell.	N.A.	R/S	5p n-5
18.F	E8	Manually write the calculated ending inventory data into respective E8 cell.	N.A.	R/S	6p n-6
18.G	E9	Manually write the calculated ending inventory data into respective E9 cell.	N.A.	R/S	7p n-7
19		To continue calculations without adjusting E1-E3 recruitment (i.e., fixed recruitment) go to Step 16.			
20		To make changes to paygrade recruitment before calculating additional yearly projections, return to Step 14 and continue program execution.			

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